Comparative Determination Of the Magnetic Qualities of Iron and Steel with the Esterline Permeameter

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A Comparative Determination of the Magnetic Qualities of Iron and Steel with the Esterline Permeameter and Magnetic Balance

A THESIS

PRESENTED BY

R. B. WENDELL
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TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

ELECTRICAL ENGINEERING

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Introduction.

At the time of choosing the subject of this thesis, the main object in view was a study of the magnetic qualities of iron and steel under various physical conditions, such as different annealing temperatures, tensions, compressions, and chillings. This field has been covered very thoroughly and satisfactorily in the past by numerous researchers; but it was thought that an added element of interest and originality would be introduced into the subject in the method intended for its investigation; that is by incidentally making a comparison between the results obtained on the Esterline permeameter and on the magnetic balance. The latter were comparatively new instruments for the kind of work contemplated, the ballistic methods formerly, having been most prominent in this field. However when we investigated the magnetic balance, we discovered that it had never been used since it was purchased nor was its operation understood. After we had consulted various sources of possible information concerning the operation of the balance, the only satisfactory source was found to be an article in a German techincal magazine. It therefore was necessary for one of us, who possedsed a very limited amount of school German, to make the translation. This task, in addition to the subsequent onc of getting the instruement in practical operation, consumed so much time that the original object of the investigation was nearly lost sight of in the operation of the magnetic balance. The latter was finaly accomplished however, but as the time remaining for experimenting was necessarily very limited, the plan originally contemplated was cut down accordingly. It ~~was~~ is thought that what results were obtained

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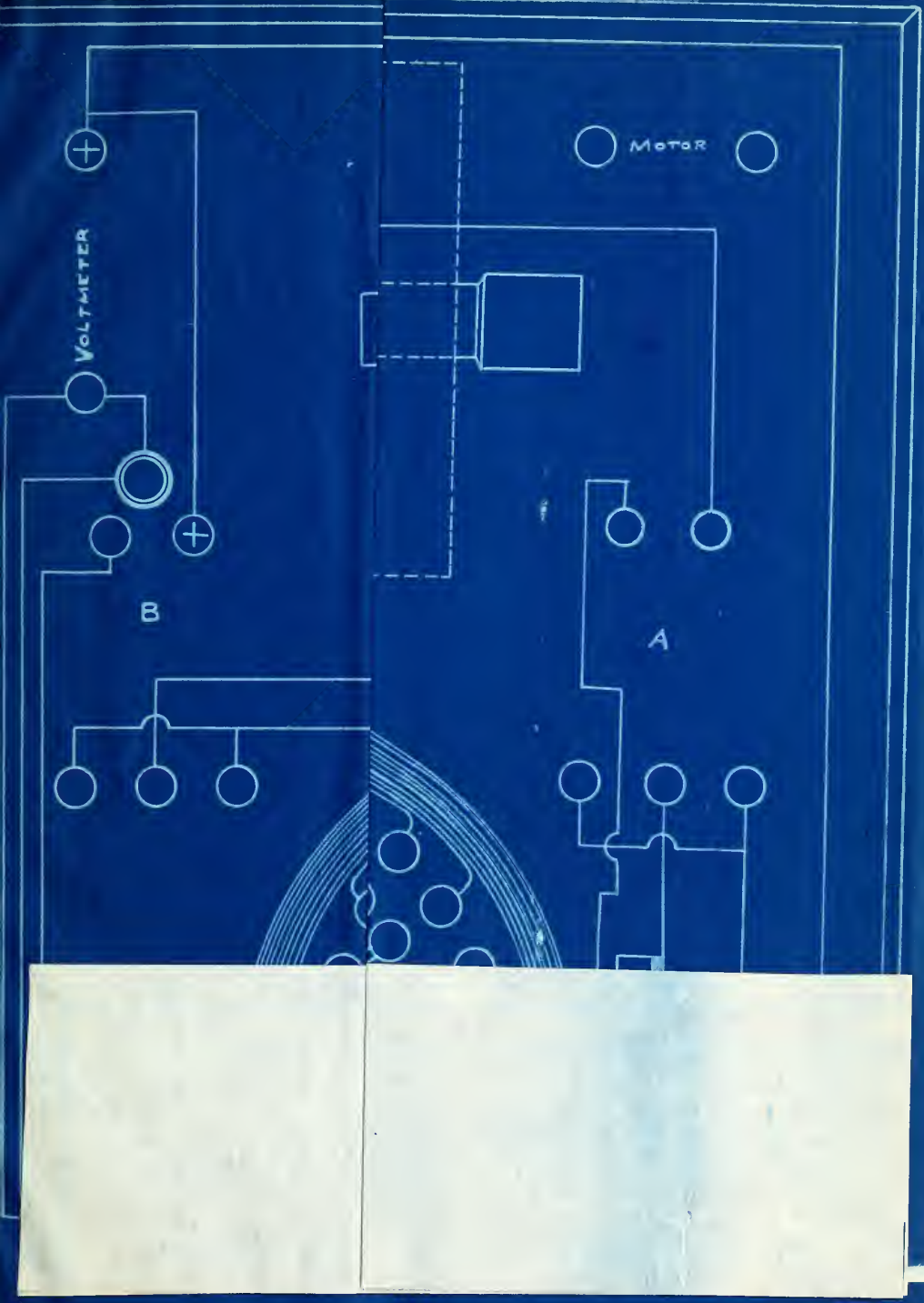

Motor
Voltmeter
B
A

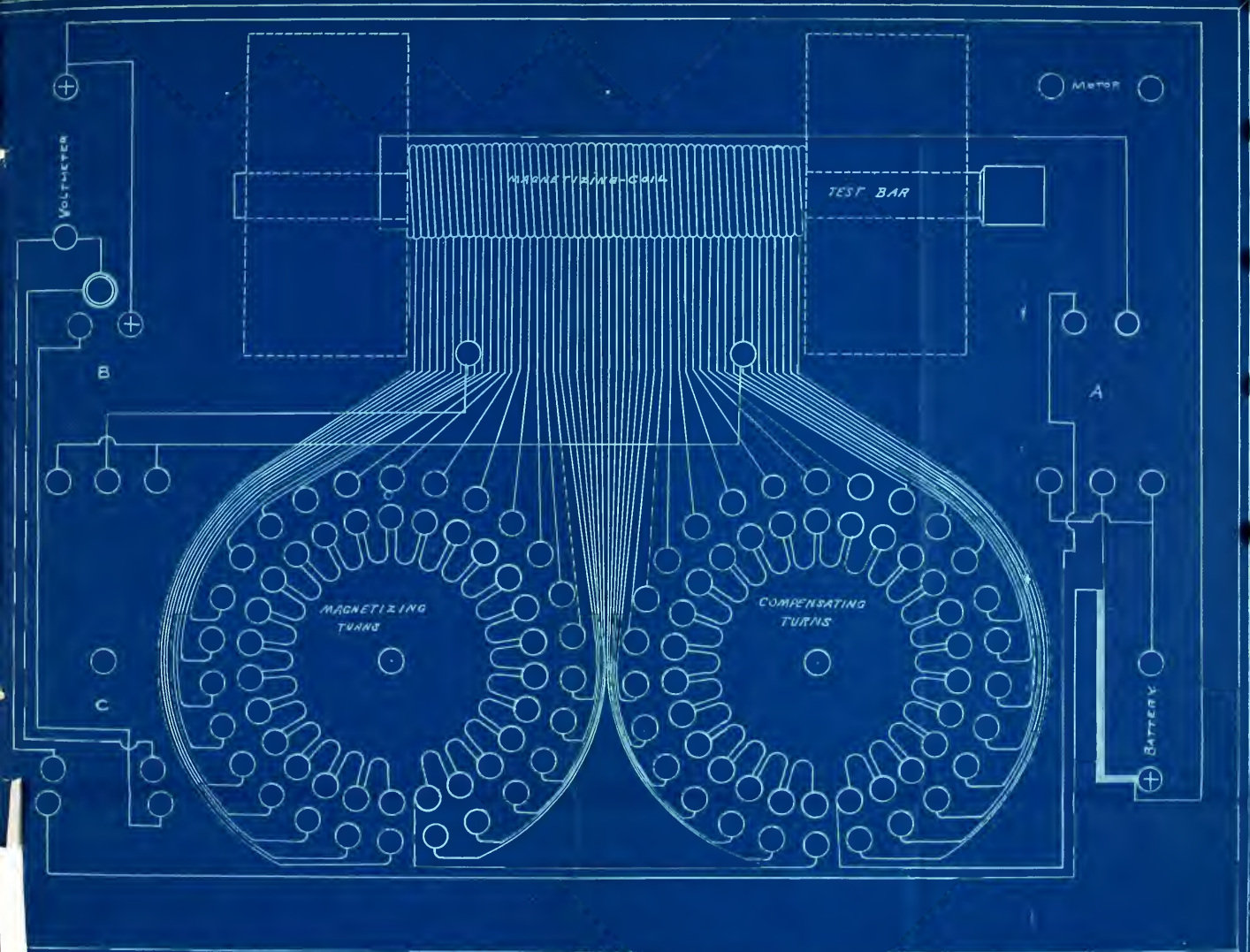
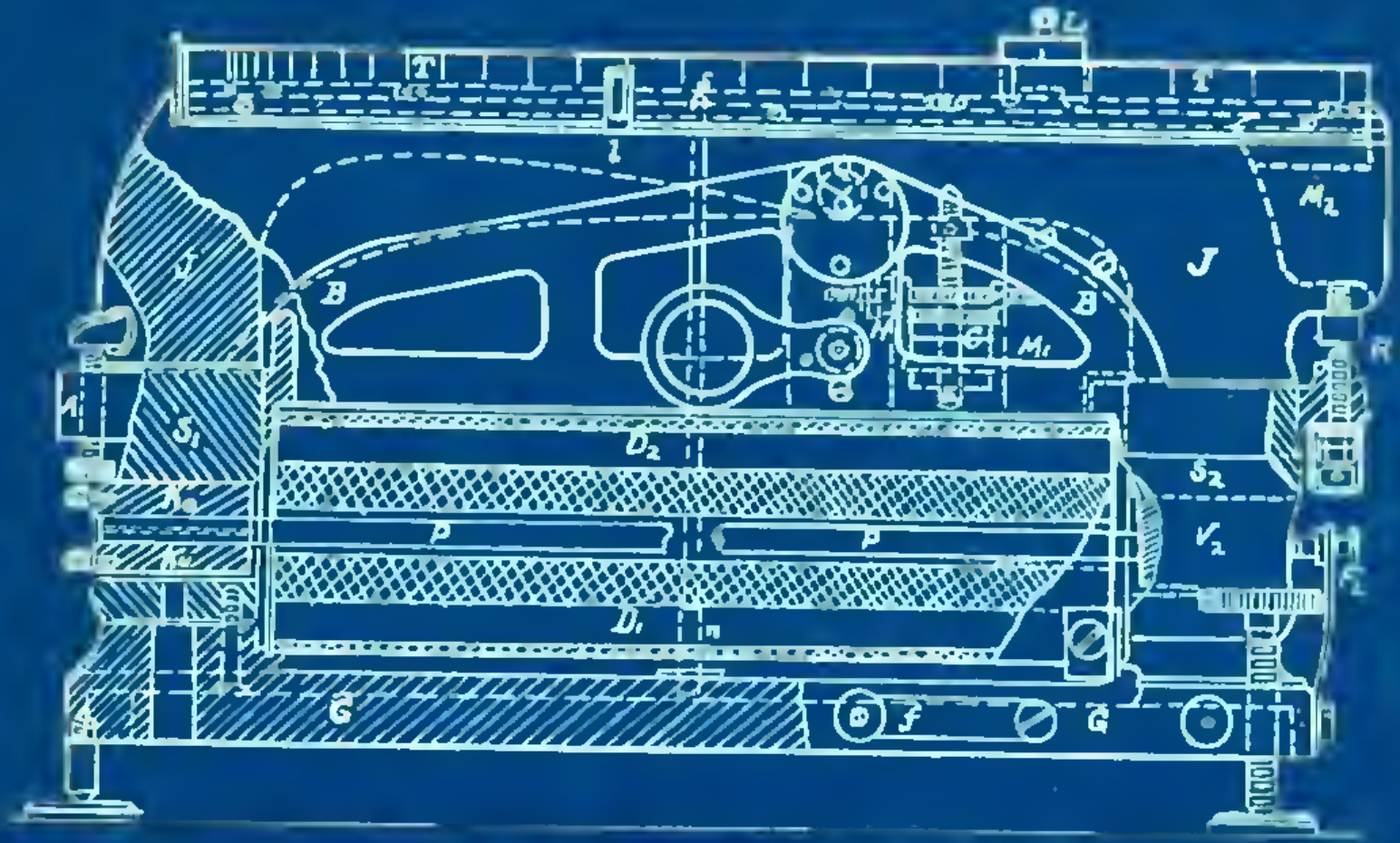
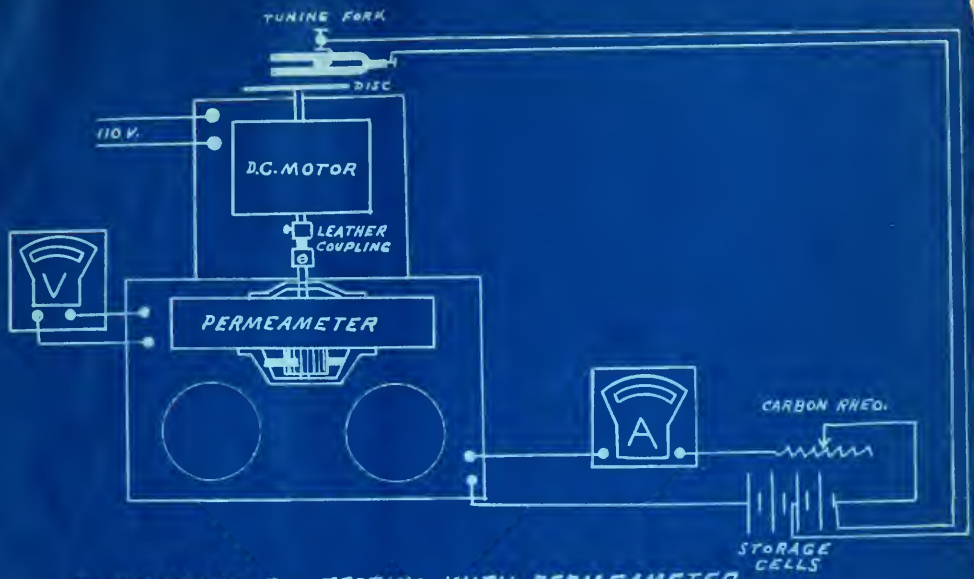


PLATE - I - ELECTRICAL CONNECTIONS OF PERMEAMETER.

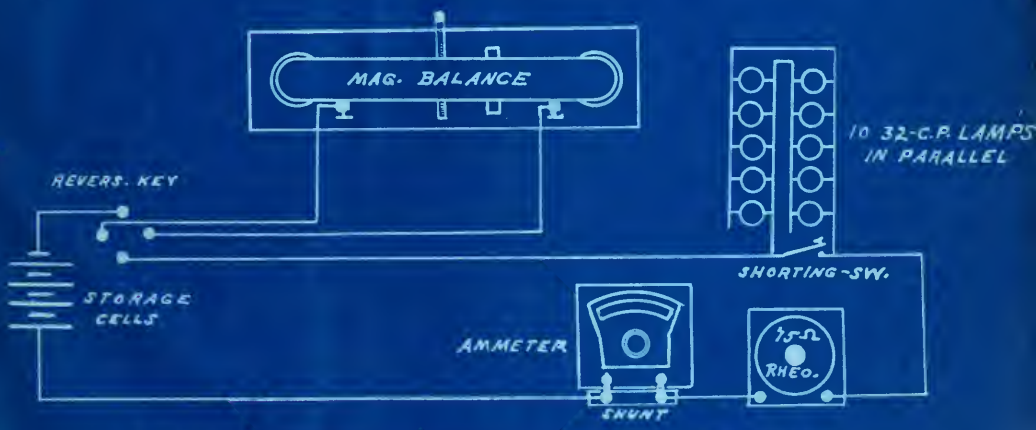


MAGNETIC BALANCE

PLATE -II-

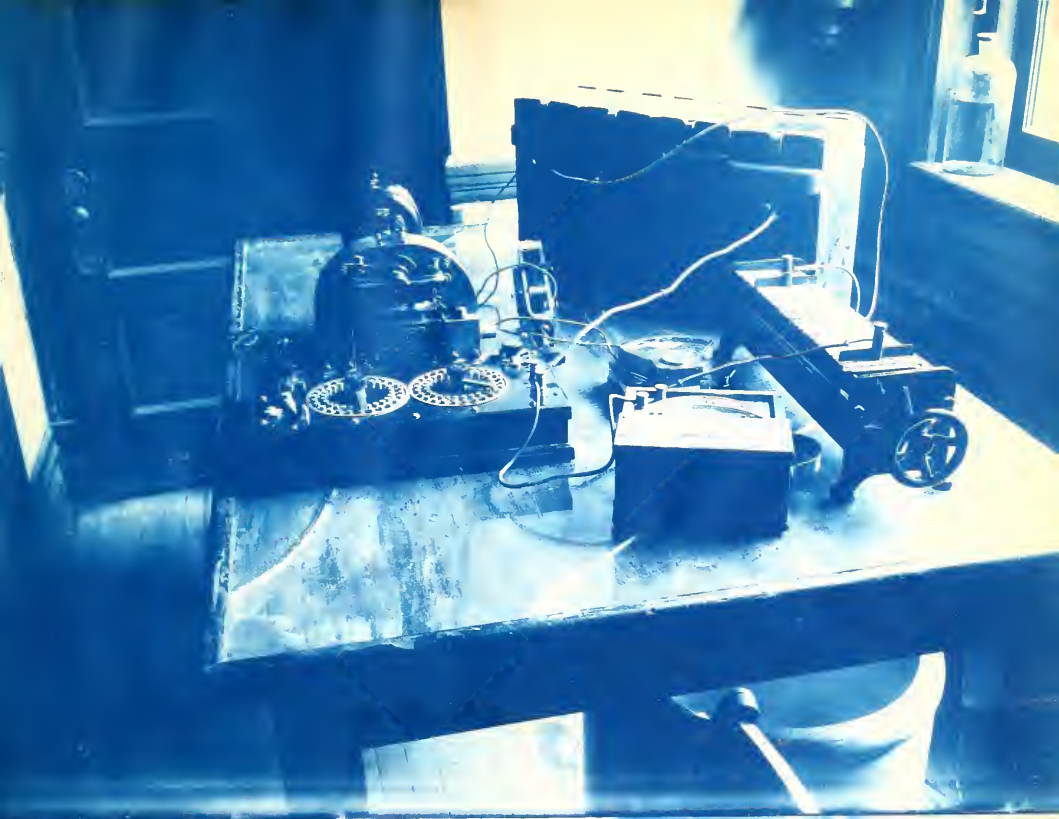


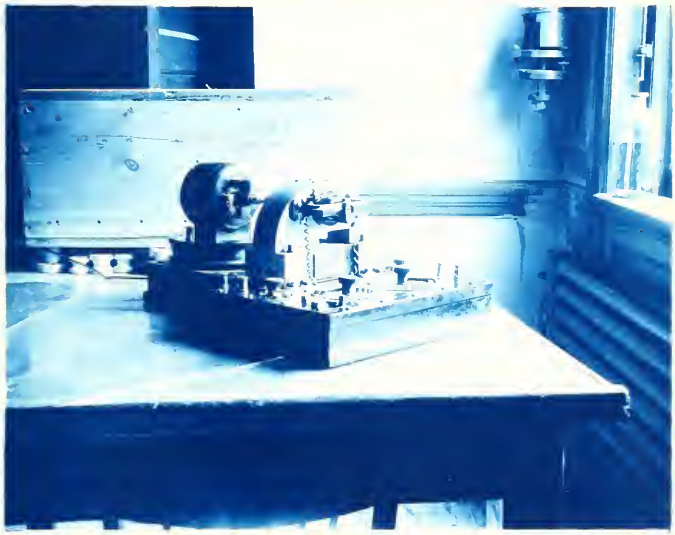
CONNECTIONS FOR TESTING WITH PERMEAMETER



CONNECTIONS FOR TESTING WITH MAG. BALANCE

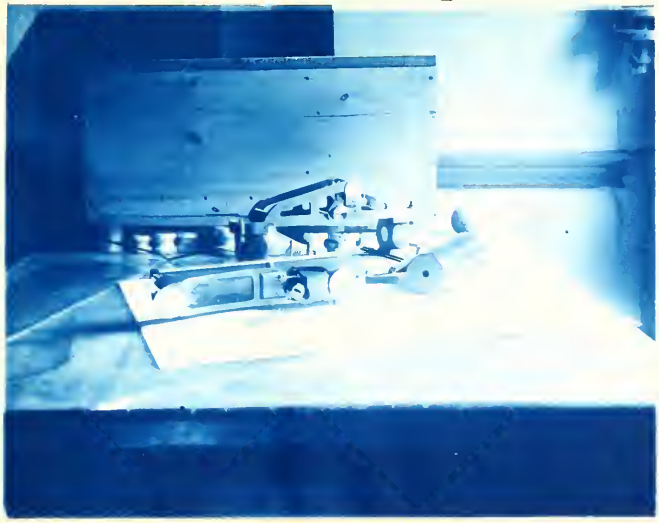
PLATE -3-

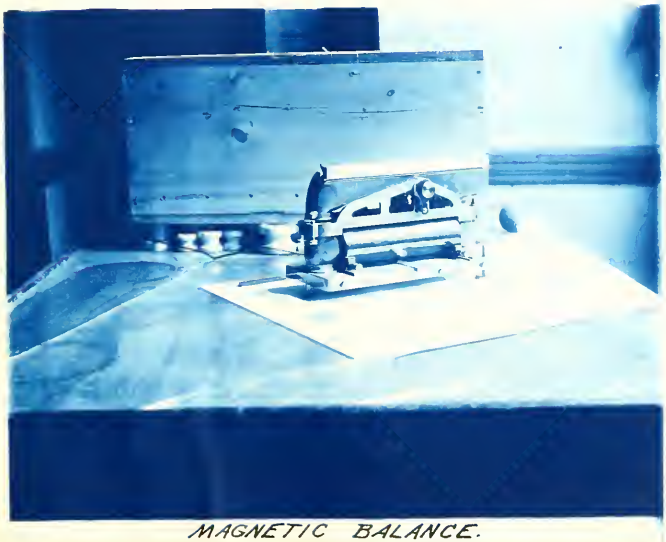




PERMEAMETER.

BALANCE DISMANTLED.





MAGNETIC BALANCE.

compresses the magnetic spherical contacts, should the automatic electro-magnetic compression be too weak in cases of small values of induction; the latter, furthermore, amounts to about 10 kg. with a saturated test piece. The maximum length of a test piece between the two vertex-points should amount to 25.4 cm. and the height of the rounded ends to .2 cm., giving a clear length of bar between the front faces of the jaws of 25 cm. and an average length of 25.2 cm or 8π cm."

"As shown in the figure, the test-piece may also be fastened in the usual manner between the clamps K_o and K_u ; of these, two pairs are furnished for standard round and square pieces. The total length of the test-piece must in this case be about 33 cm., making the clear length 25 cm or less. The jaws as well as the clamps measure between their front faces and the tips of their brass-knobs just 5 cm. The latter distance is determined by means of the divided measuring rods accompanying the instrument, and this must deduct 10 cm. from the clear length of the test piece."

"The jaws fit in the two steel bases S_1 and S_2; the upper clamps, and also the upper halves of the jaws, bear on a contact surface of about 18 square cm; by means of pressure an inner contact can be established with the ground-out base-boring; this pressure is exerted on two projecting screws on the front edge of the base plate. However, it is to be recommended that the right-hand screw be removed and that in its place an accompanying brass rod be put, the necessary pressure being furnished by a weak snap spring without producing unnecessary pressure, which would, under a

the circumstances, influence the magnetic property of the test-piece".

"The bases are screwed on their lower ends to the brass base plate "GG" and are rigidly connected on their upper ends by a shrunk-on brass bridge,"BB". This also carries an arrestment for the knife edges "Q" of the balance beam corresponding to the yoke, "JJ", which is placed eccentrically 4 cm. distant from the middle of the apparatus. The pairs of parallel, polished, and well centered, four circular faces of the bases and yoke have about 18 square cm. area and enclose two air gaps of which the widths should be closely alike and approximate .025 cm. The regulating screw, "R", of hard unoxidized phosphor-bronze carries a lock nut and one with two projections for the alignment of the protective cap. These suspend the yoke by two contacts points after the manner of the Morse key with a play of about .01 cm. above the regulating screw,"R", and on the left the indicated contact screw,"A"; the latter prevent immediate contact between yoke and bases."

"The making of the yoke out of steel permits a freedom of shaping which, in the first place, guarantees a complete rigidity against bending, secondly, permits the finishing of the upper parts as geometrical guides for the riders "L" and "l", and thirdly, by means of two balancing weights "M_1" and "M_2" is accomplished an approximate balance

A vertical adjustable counterweight, "C", and a horizontal movable one, "H", serve for a further adjustmentof the balance beam. The average cross-section of the yoke is 20 square cm., its total weight 8 kg., and the remaing parts weigh 14 kg.

"The steel parts are carefully annealed after working them and in fact, like one in the Royal Institution, are usually raised to a red heat. It appears doubtful if one could make the yoke out of solid hardened steel, hence at its ends are inlaid steel plates which with those under the 90 degree ground prisms, form a whole one; therefore the sharp edges are purposely somewhat flattened. By this means and due to the rigid arrangement of the yoke and brass bridge every variation in the width of the air gap is without exception indicated, upon which the accuracy of the instrument depends."

"On the upper edge of the yoke is to be found a light quadratic scale,"TT",(in the figure only a few scale divisions are shown) which actually carries two rows of figures; the upper row in the black for the heavy weight"L" of 65 gm., the under row in red and five times smaller values corresponds to the 25 times lighter rider,"l", of 2.6 gm. These numbers multiplied by 100 give the induction in C.G.S. units directly. The larger weight serves for ranges of induction from 5,000 C.G.S. units upward and the smaller one for the smaller inductions, such as are used in transformer plates; for obtaining cyclic curves for various materials the above limits are suitable corresponding to all average claims able to be made."

"In the middle of the base plate moving from front to back is a brass slide working in a groove; on the front end this carries a small knob-like index and behind it carries two receptacles in which the north poles of two independent, strong, vertical compensating magnets can be placed. By shifting one or both

magnets to a suitable position a vertical component of the magnetic field can be put in place of the vertical component of the earth's magnetic feild, so that otherwise possible fields have a component opposing them. The base plate also carries two parallel cross-slides on which theexciting coil slides easily so that it may be moved out of its central position between the two bases. This consists of an inner coil,"D", which is wound with 12 layers of 200 turns of .1 cm. stout copper wire; this is surrounded by a brass tube which also carries two outer coils, "D_2", of 200 turns each. The two separate coils are bound together and arranged one after the other so that the current flows in opposition in them. The current strength in centi-amperes is numerically the same as the field intensity produced; the 100-fold reading on an ammeter and on the scale of the yoke gives therefore the (uncorrected) abscissae and ordinates determining the induction curve".

"Generally a current range up to 3 amperes will be sufficient; when investigating saturation points a current up to 5 amperes can be employed. During the short time necessary until the finish the undue heating of the coil should not be permitted. In order to prevent a possible rise in temperature of the test-piece a nozzle may be added: this may be fixed at the end of the coil and permits the blast from a bellows to circulate between the test-piece and inner coil. In order to prevent warm air currents from flowing around the yoke therby, the coil is covered by a sheet metal protecting plate attached to the bridges,"BB".

"The functions of the balance can be limited by the application of the ballistic method to the closed yoke; this commends

itself in regions of very weak fields where the weighing on the quadratic scale would not be accurate enough. For this purpose two thin iron discs with brass handles are provided which are able to close up the gaps, and further a coil which carries only 20 uniformly distributed primary turns so that its field will be numerically the same as that of the exciting current in amperes; besides it may be wound with from 1000 to 5000 secondary turns to make it available in accordance with the sensitiveness of the ballistic galvanometer."

Description.

"For measurements of percision, precautioary measures are, of course, to be encountered, of which, many, for technical work, may be disregarded without materially affecting the results. To avoid possible small influences of the earth's field, the balance is placed lengthwise east and west; to guard against jarring, it is well to place three india-rubber discs under the supports. The scale should be placed on a level with the eye. The upper base faces are leveled by means of an air bubble; the yoke is lifted off and placed with its back side resting on two supports; for for the first adjustment the knife-edges are made to rest on two small glass plates supported so the beam swings free; its period of swing is brought, by means of the vertical counter balance, to 30 or 40 seconds which usually will give sufficient sensitiveness; by means of the horizontal counter balance the upper edge may be set approximately level. After cleaning the knife edges and bearings the yoke may be placed upon the arrestment; after the

conclusion of every run always make the arrestment and cover the instrument with the case."

"The coil has a resistance of about 6 ohms; with correct adjustment, the direction of the current from terminal to terminal may be made the same as the direction of the field of the inner coil; the outer compensating winding should work in opposition as is shown by a small magnetic needle. To the full field range at 500 C.G.S. units corresponds a current of 5 amperes under an electromotive force of 30 volts. There should be a variously graded resistance of 10,000 ohms at hand so that a current down to .5 centiampere can be obtained without difficulty corresponding to numerous corresponding fields and gradually return as far as desired."

"An ammeter and reversing key are placed incircuit so that the current can be obtained in convenient steps and reversed and measured. In case the ammeter contains a permanent magnet it must be placed as far as possible - at least one meter - from the balance. The same holds true of articles of iron and steel, to prevent interference due to induction. By continual increase of resistance the thorough demagnetization of test piece and yoke is effected by"decreasing commutations", as is well known. For technical work involving small current ranges simple auxillary apparatus is permissible, in particular liquid resistance and carbon rheostats by means of which the resistance is regulated by pressure; these various accessories are not desirable for accurate work, in that the intermupted even increase or decrease of the field strength would cause error."

"In consideration of the subject of the test piece the follow-

-ing is to be said. With solid soft material a circular form is naturally preferable; after turning up, the bars are ground to a uniform cylindrical shape with a diameter of .708 ± .001 cm. The spherical contacts according to the before mentioned dimensions of .5 cm. radius, are turned up on both ends with rough grinding on an emery wheel. Next, the convex faces are ground out by means of a copper grinding sphere and emery; futher treatment with a polishing powder will generally suffice. The spherical contacts must be rounded off in the afore mentioned manner. By means of a light coating of soot in a candle flame one gets a convenient indication of the excellence of the magnetic contact between the convex ends of the test piece and the concave-ground jaws, in which by light contact the thin uniform layer of soot is rubbed off."

"The spherical contacts are not only to be perferred theoretically but the following practical facts are also noteworthy: The test-piece centers itself entirely automatically even when slightly bent as occurs in hard steel, whatever its cross-section is. The spherical contacts were given a rigid test by Hrn. Föppl in Munich technical laboratory reducing to what is desired in many magnetic determinations. There was finally proved a saving of material as opposed to the use of the clamps requiring a total length of 33 cm."

"Next the use of the compensating magnet is to be followed. For this latter, a rod of soft material is clamped, and the induction for a high field strength - about 150 C.G.S. units - with the heavy rider is read off, whereby appears a difference of about 400 C.G.S. units between both directions of induction. After ten prelim-

-inary commutations, one or both magnets are placed in the receptacles and these adjusted along the scale divisions so that the inequality of the readings dissappears. Hereby one must guard against possible residual magnetism of the test piece in consequence of previous strong magnetization."

"For the benefit of the exact control of the zero point, it is well to demagnetize the whole apparatus thoroughly and in behalf of certainty repeat the action once more with the test bar alone, in which case the coil is moved out; with good soft material this is accomplished without trouble, the induction being held under the value of 100 C.G.S. units. Under this condition (thorough demagnetization) in case both riders are exactly at zero the yoke should immediately become loosened from the right hand regulating screw,"R", otherwise correction may be made by counterweight,"H". This loosening is shown by means of a small slit observed by the eye or by touching with the finger tips, and is a sharp, well defined balance criterion, generally decisive for all readings. (It is well to place a piece of white card-board behind the balance)

The error of current measurement must, of course, not exceed the limit of error set for the induction; accordingly, temperature corrections for the arreter are to be considered.

With regard to the balance itself it barely approaches room temperature; with the extension of the field range above 150 C.G.S. units it is well to employ the blast funnel.

The treatment and magnetic history have an influence on the general characteristics to follow; in particular for obtaining cyclic induction curves at least ten of the same range of cyclic

measurements should be taken, of which use should be made of only the least two. The compensating magnet is always to be commended for the determination of a complete hysteresis loop of 40 to 80 points for the desired accuracy; The average is then obtained from the positive and negative halves. Sometimes doubt arises as to interpretation of a reading on the quadratic scale as to whether it is positive or negative, which becomes evident from the fact that one of the two points representing the observation falls entirely outside the curve."

If the standard cross-section of half a square centimetre cannot be obtained, the observed value of induction is to be divided into double the cross section; the latter should in no case vary over 1 per cent from the normal value."

"In the large free space between the protection plate and the base, many other arrangements can be put in place of the exciting coil, as, for example, in investigations for the effect of high and low temperatures, of tension or compression on the magnetic qualities of the test piece, of which the length can be reduced to 2π centimeters."

"Thus for different purposes it lends itself to the nature of the investigation unrestricted by hard and rigid construction".

The above description and use of the magnetic balance covers all the important points; the mathematical theory of the instrument will not be given here but it may be obtained from the same article previuosly referred to.

The description mentions two compensating magnets but the balance used in this work was provided with only one. This ~~work~~

π

one magnet was not quite strong enough for its purpose, though it was strogly magnetized several times. Hence we used a more powerful bar magnet in place of the one provided and this proved satisfactory. The method of adjusting the compensating magnet might be made a little clearer, possibly, than is given in the description. A magnetizing current of from one to one and a half amperes is sent through the coil. The heavy rider is placed on the right hand end of the scale and slid towards the left until the point of balance is reached as indicated by the parting of the face of the yoke from the right-hand screw,"R". Then the current is reversed several times and left flowing in the direction opposite to what it was before. The above operation is repeated and the point of balance as read on the scale will be the same for both directions of magnetization if the magnet is properly adjusted. This is simply a matter of trial and is sometimes very tedious. The position of the magnet was adjusted for each individual test-piece. Sometimes the particular position the magnet was in was correct for several test pieces and then in error for some other test-piece. This may have been due to a change in the magnetic field surrounding the instrument, though all pieces of iron were kept at fixed distances during a run in order to preserve constant magnetic conditions as far as possible. The change might possibly have been due to a difference in test pieces also.

One important point, as we soon found, that was not mentioned in the article referred to, was the method of moving the heavy rider along the scale. To get consistent results it was necessary for one of us to read the point of balance and the other to move

the weight along the scale. First we tried moving it with the finger and then by tapping it with the end of a pencil. Both of these methods gave fairly constant results but the points of balance as determined by them did not agree. As the balance was very sensitive near the point of equilibrium a slight downward component of a tap on the weight would of course tip the yoke a little too soon. In order to obtain a uniform method of moving the weight by pushing or tapping it in a horizontal direction, two upright pieces of wood with holes bored horizontally through their upper ends were nailed to the table several inches apart and a few inches from the right hand end of the balance. Through these holes slid a copper rod of sufficient length to enable the rider to be pushed to the zero position on the scale. This rod might have been of any non-magnetic substance. By means of this arrangement very delicate manipulation was possible and points of balance could be made to check each other as close as it was possible to read the scale: Of course the position of the compensating magnet had a good deal to do with this. Further, by using this rod for moving the rider, the whole apparatus could be operated by one person if necessary. To lessen the fatigue of the eyes in watching for the point of balance, a small pocket lens was placed in front of the right hand screw,"R", where the break occured at the point of balance. When the point of balance was out at the left hand end of the beam the sensitivenss of the instrument was increased. Hence, as is suggested on the description of the instrument, the small rider alone was used for the values of induction below 5000; this, of course, corresponded to the point

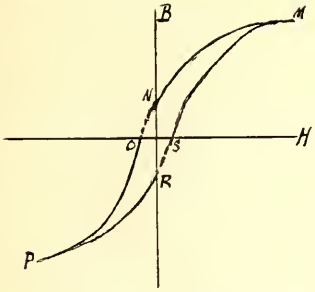
marked 50 on the top scale . By placing the large rider at zero and moving the smallone along the scale from right to left with the finger, the point of balance could be accurately obtained; the reading on the upper scale divided by five gave the correct scale reading when using the small rider. It was not necessary to use the small rider for more than two or three points when determining a hysteresis loop, and sometimes it was unnecessary to use it at all.

As the maximum value of field strength that could be obtained on the permeameter was 100 C.G.S. units, the same limit was put on the field strength when ~~when~~ using the balance in order to reduce the results to the same basis. A field strength of 100 C.G.S. units with the balance corresponds to a current strength of one ampere. The method of obtaining the unbroken current steps necessary for a hysteresis loop is indicated inthe connections for the balance on Plate 3. The most satisfactory form of variable resistance was found to be that shown; that is, ten 32 C.P. lamps in parallel with a short circiuting switch across them, and in sereis with the lamps a 75 ohm field-rheostat. By use of four storage cells in series, a complete current range from zero to one ampere could be obtained in as finely graded steps as it was possible to read on the ammeter. The ammeter was a Siemens and Halske mil-ammeter graduated up to 150; it was provided with 2 ampere and 7.5 ampere shunts of which the use of the former made it only necessary to multiply the ammeter readings by two in order to obtain C.G.S. UNITS directly. By limiting the maximum current to one ampere abmormal heating of the coil and test piece was prevented and

hence the use of the blast funnel mentioned in the description was not needed; as a test five amperes was found to heat up the coil and the test piece considerably so that under this condition a cooling device of some sort would undoubtedly have to be used.

The operation of the permeameter will not be discussed for reasons already given but a few facts bearing on theauxillary apparatus will be mentioned. The main thing, in using the pereameter, is to hold the speed constant at 1750 R.P.M. at which speed the milli-voltmeter was calibrated. It was figured that by using a seven-spot disc on the motor shaft, a speed of 1750 R.P.M. would be indicated by using a tuning fork of 204 single vibrations per second. A tuning fork with adjustable weights was therefore calibrated against a standard fork, for this frequency. Two storage cells operated the fork satisfactorily and by pressing lightly with a piece of waste on the rubber plate cover of the pereameter, the required speed was readily obtained. The necessary exciting current of ten amperes was supplied from four storage cells in series as shown in the scheme of connection for the pereameter on Plate 3. A carbon rheostat and ammeter were placed in circuit with the battery. A switch on the permeameter makes it possible to read the current on the milli-voltmeter; but to avoid throwing the switch for each reading, an ammeter was used. This ammeter was calibrated twice; the 10 ampere point according to the first calibration was 10.24, and according to the second calibration several weeks later it was 9.95. Most of the data on the pereameter was taken with the second calibration and the ammeter was not used for any other purpose.

One rather serious fault we found with the pereameter, for which we could find no practical remedy, was the impossibilty of obtaining those portions of the hystersis loop occurring in the second and fourth quadrants. To illustrate this when the point



N was reached on the curve MN, the magnetizing turns were zero but there were still some compensating turns still in, depending on the residual flux. Upon reversing the current to obtain the curve in the second quadrant, it was found that the bar being tested was rapidly demagnitized though no magnetizing turns were in circuit. Evidently this demagtizing effect was produced by the compensating turns. Reducing the compensating turns to zero did not help matters either and as there was no way of reversing the current separately in the compensating turns, it was decided to omit those portions of the curve in the second and the fourth quadrants. After taking the reading at a point "N" therefore, the compensating turns were reduced to zero, current was reversed and magnetizing turns were cut in until the flux was reversed as indicatedby the direction of the milli-voltmeter deflection, and the curve "OP" was obtained. The dotted portion of the curve "NO" was simply filled in. Just the portion of the curve "MNOP" was obtained on either the magnetic balance or the pereameter; the other half was assumed to be symmeterical as was proved several times on both instruments, the balance in particular proving that the second half of the curve was nearly equal to or identical with the first half, on several occasions.

The test pieces for both balance and pereameter were of cylindrical bar form. For the balance they were 33 cm. or 13 inches long and finished to a diameter of .798 cm. or .314 inches. For the pereameter the bars were 10 inches long and finished to a diameter of .575 inches. It might be mentioned here that both instruments have means of testing sheets of iron as well as bars. The materials tested for magnetic qualities were wrought iron, soft steel, and cast steel or tool steel, the letter being very hard. With the exception of one piece all the samples, twelve in number, were so cut up that the same material was taken from the same bar, in order that the structure and composition might be as homogenous as possible for a given material.

In order that the cast steel might be machined it was raised to almost a white heat and then covered with lime and left to cool for 24 hours.

The wrought iron and soft steel were machined without this annealing. The heating due to machining was kept moderate by dropping water on the test piece while being turned. Test-pieces intended for tension tests were made several inches longer than those for the temperature tests, so that the jaws of the testing machine would not scar the surfaces of the test pieces where good magnetic contact was necessary in the instruments. When the test pieces were turned up they were placed on a somewhat equal starting basis by heating them up to 1400 degrees Faherenheit and plunging them in water. This temperature brought the samples to a dull red heat and the chilling made them sufficiently hard to start

annealing tests with. After this chilling all the samples were tested on the magnetic balance and permeameter in order to obtain the initial set of B-H curves. As stated before, there were twelve samples in all; a temperature test-piece, and a tension test-piece for each of the three materials, or six samples for each instrument.

The plan followed in the annealing process was to heat the six annealing samples at a certain temperature for two hours, after which the samples were tested. Again they were heated for two hours more at the same temperature and again tested. This second heating for two hours was the same as heating steadily at that temperature for four hours, as is stated in the "Proceedings of the Royal Society", volume 64, page 150, where it says,"The heating need not be continuous; the same cumulative effect is produced by a number of short periods at a given temperature as by continuous heating at the same temperature". The annealing was done in a gas annealing furnace in the forge shop. To keep, as far as possible, the samples from blistering , each was placed in a suitable length of iron pipe sealed at both ends with fire clay; all six annealing samples were annealed together. After a period of heating the samples were allowed to cool in the furnace, which required fifteen or sixteen hours. Temperatures were recorded by a Bristol electric pyrometer which consisted of a platinum-iridium couple connected to a calibrated milli-voltmeter, the latter indicating up to 2000° F ahrenheit. The tensions applied to the tension samples were obtained on a Riehle testing machine .

The plan followed out in making all tests is given on Page 19.

Plan of Tests.

Annealing Samples (6).

Annealed at	Heated for	Heated for
750° F.	2 hours (Tested)	4 hours (Tested)
1000° F.	2 hours (Tested)	4 hours (Tested)
1800° F.	2 hours (Tested)	4 hours (Tested)

Tension Samples (6).

Area balance sample = .0775 sq.in. Area per Beam. sample = .26 sq.in

Material	Tension lbs.per sq.in.	Actual load Per Beam. sample	Actual load Balance sample
Soft Steel	5,000	1,300	390
	15,000	3,900	1,170
	25,000	6,500	1,950
	50,000	13,000	3,900
Cast Steel	11,900	3,000	924
	30,000	7,800	2,340
	50,000	13,000	3,900
	90,000	23,400	6,975
Wrought Iron	5,000	1,300	390
	10,000	2,600	780
	15,000	3,900	1,170
	22,000	6,000	1,700

The tabulated results of the tests made with the balance and permeameter are given in the data sheets following. From these data were plotted the seventy-two curves. In many cases, plotting complete hystersis loops as obtained from both instruments, on the same curve sheet, would have caused considerable confusion. To avoid this, simply the average of each loop was plotted, the dotted curve representing results obtained on the magnetic balance and the continuous curve representing permeameter data. From these average curves were obtained the values of permeability as tabulated on each curve sheet. The values of permeability thus obtained are tabulated on the data sheets following the curves in such a form as to facilitate comparison of values of permeability of a given sample under the various temperatures and tensions.

With reference to the data sheets just mentioned, those dealing with the annealing samples will be considered first. As is well known, permeability is increased by annealing. This fact is clearly demonstrated in the change from the initial condition of the samples to the first period of annealing. The increase of permeability at this point averages 6.9 per cent for wrought iron, 8 per cent for soft steel, and 13.6 per cent for cast steel. The averages are given as the average values of the two methods of testing. Since in their initial conditions the samples were very hard after the chilling process mentioned previously, the effect of the first annealing is very noticeable. Subsequent heatings, however, do not show the variations that were expected. What little variatio that is shown is most noticeable for the lower values of magnetizing force; the maximum values average nearly constant for the permeability. Some of the samples show values that are far

from satisfactory; however, the same sample was tesed each time under as constant conditions as it was possible to maintain. As a matter of fact, longer periods of heating would have given better results, perhaps, but the time required for such heating was not at our disposal. Assuming that the materials tested were to be used for electrical purposes, it may be said that the permeability would only be slightly improved even by heating at 1800° F. for four hours. If the materials were to be used under the conditions of strong magnetization, practically no change of permeability would be effected by the annealing temperatures and the lengths of heating that we employed.

Considering the data obtained from the tension samples, the results probably nearest the truth under such conditions are those obtained with cast steel on the magnetic balance. These show that the value of permeability tends to become less as the tension is increased as is generally believed to be the case. The effect of tension seems to be the most pronounced with cast steel; with wrought iron the permeability remains practically constant throughout the values of tensions, according to the data obtained on the magnetic balance. Apparently, the materials tested could be subjected to stresses as high as their elastic limits without greatly impairing their permeability; the stresses were only applied for a few seconds in the materials tested.

In order to find the average per centage variation in the results of the two tests the average per cent difference in permeability was figured for each set of conditions, using the results obtained on the balance as a per centage basis. Out of

thirty-five tests made, the permeameter read on an average 6.56% higher than the balance in 15 tests and 7.75% lower in the remaining twenty tests. That is, the permeameter indicates a little over one per cent lower than the magnetic balance, taking the curve as a whole. However on the steep portion of the curves, with magnetizing force of 20 C.G.S. units the permeameter averages about 8% less than the balance; on the flat part of the curves with a magnetizing force of 100 C.G.S. units, the permeameter ~~indi~~ indicates a permeability averaging about 3% higher than that of the balance.

There are four principal features to be desired in an instrument designed for practical magnetic testing; (1) Samples should be easily, quickly, and inexpensively prepared; (2) The method of testing should be rapid and yet give high relative accuracy; (3) The apparatus should be simple and unaffected by vibrations, magnetic fields, etc.; (4) Instruments should be direct reading, requiring little or no calculation in deducing results.

Both instruments possess the advantages of the first feature; the samples of both are of straight, cylindrical, bar form. Owing to the smaller diameter of the balance samples, extra precautions must be taken in turning up the bars to provide against the sample springing between lathe centers. The fact might be mentioned that though the permeameter samples were finished to exact diameters of .575 inches as per directions, the samples could not be made to enter the permeameter until the diameters had been reduced about .002 inches, some driving being required even then.

With regard to rapidity of the methods, they were both found

to require, on an average, ten minutes to obtain one half of a hysteresis loop. The relative accuracy of the balance is on the whole, higher than that of the permeameter; and results once obtained on the balance can be duplicated more ~~easily~~ closely ~~than~~ again than they can on the permeameter, in the majority of cases. As to the absolute accuracy of the methods, the only way to establish this would be a comparison of results obtained by the ballistic method. This, of course, would have required considerable time, but the chances are that the balance possesses the highest absolute accuracy on account of its better construction and greater sensitiveness.

As to the simplicity of the instruments alone, the magnetic balance possess the greater electrical simplicity, having simply the magnetizing coil. The permeameter circuits, on the other hand are somewhat complicated, as seen from the diagram of connections preceding. The magnetic balance, however, is not so simple mechanically as is the permeameter; a very high grade of skill is evidenced in the perfection of the finish of the various parts, and incidentally, this would make the balance the more costly instrument. As to the effect of vibrations and magnetic fields, the advantage is all on the side of the permeameter. The passing of heavy wagons and trains, or even walking across the floor, make accurate readings impossible on the balance; and the trouble of neutralizing magnetic fields with the compensating magnet has been mentioned.

Both the magnetic balance and the permeameter possess the advantage of being direct reading instruments, to an equal degree.

The only occasion for doing any calculating is when it is desired to change from one system of units to another. The C.G.S. system was used in all our data and curves; as the balance is based on this system no change whatever was made in its readings; but to change the ampere-turns per inch on the permeameter to C.G.S. units of magnetizing force it was only necessary to multiply the ampere-turns per inch by the constant .495; and the induction density in lines per square inch as obtained on the permeameter was divided by 6.45 to give lines per square centimeter.

The four principal features of the instruments as previously enumerated have been covered in the above discussion, but a few minor considerations may be added. In the matter of auxillary apparatus the two instruments have in common , storage cells, reversing switch, ammeter, and variable resistance: the permeameter voltmeter was also intended to used as an ammeter so these two instruments may be considered as one. The range of the resistance for the balance is enormously greater than that required for the permeameter, but it is not difficult to obtain this range of resistance by using incandescent lamps. In addition to the apparatus in common for the instruments as mentioned above, the permeameter requires a driving motor and some method of speed control, such as a tuning fork. The permeameter requires a larger amount of energy than the balance, ten amperes being the constant magnetizing current. This comparatively large value of current has the disadvantage of heating the test piece considerably, if it is left for any length of time in the permeameter, and this has its effect on the values of induction. One thing noticeable at times

with the permeameter is that the voltmeter will fluctuate five or ten scale divisions even though the speed is being held as nearly constant as at other times when the readings are nearly absolutely steady. Of course, in such cases only a rough average reading can be taken. This fluctuation is most noticeable for high values of induction and probably occurs in cases where the sample has a high value of permeability. Another thing against the permeameter is the impossibility, as we found it, of obtaining those portions of a hysteresis loop occuring in the second and fourth quadrants as was pointed out before. The permeameter also requires two operators, one to take the readings and another to keep the speed constant; the magnetic balance may be worked by one operator as was done several times. The chance for personal error is greater with the balance, depending on the manner in which the rider is pushed along the scale.

Summing up, then, the choice of the two instruments seems to fall upon the magnetic balance whose worst faults are its sensitiveness to vibrations and magnetic fields. With proper precautions against interference from these two sources of error, the magnetic balance will be found to give results thoroughly consistent and accurate.

Data for B-H Curve of Wrought Iron(1) in Initial Condition.

Obtained on Magnetic Balance.

B	H	B	H
20650	100.00	2600	&1.60
20300	79.00	-11500	-6.00
20150	61.34	-12100	-8.40
19000	39.34	-13700	-12.00
18300	30.66	-14800	-14.00
17000	23.00	-14900	-16.00
15000	15.00	-16050	-20.66
14150	10.00	-18200	-37.00
13700	8.00	-18800	-50.00
12800	6.00	-19450	-74.00
9850	1.60	-19900	-90.00
7400	0	-20000	-100.00

[illegible]

Data for B-H Curve of Wrought Iron (A) in Initial Condition.

Obtained from Esterline's Permeameter

b	B	h	H
127000	19700	1000	99.00
126500	19620	880	87.12
125500	19460	800	79.20
123500	19160	640	63.36
120000	18600	520	51.48
115000	17840	360	35.64
110500	17150	320	31.68
109000	16900	280	27.72
102500	15900	240	23.76
100000	15500	200	19.80
98300	15240	160	15.84
90000	13950	120	11.88
83000	12870	80	7.92
71000	11000	40	3.96
49000	7600	0	0
-5000	-776	-40	-3.96
-49000	-7600	-80	-7.92
-68000	-10540	-120	-11.88
-81500	-12630	-160	-15.84
-90000	-13950	-200	-19.80
-93000	-14420	-240	-23.76
-96000	-14900	-320	-31.68
-97500	-15120	-360	-35.64
-102000	-15820	-400	-39.60
-105000	-16280	-520	-51.48
-109000	-16900	-640	-63.36
-110500	-17150	-760	-75.24
-114000	-17700	-880	-87.12
-119000	-18450	-1000	-99.00

MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	16300	815
40	18650	466
60	19600	327
80	20000	250
100	20250	203

PERMEAMETER

$\mathcal{H}$	$\mathcal{B}$	μ
20	14650	733
40	16900	422
60	18000	300
80	18650	233
100	19200	192

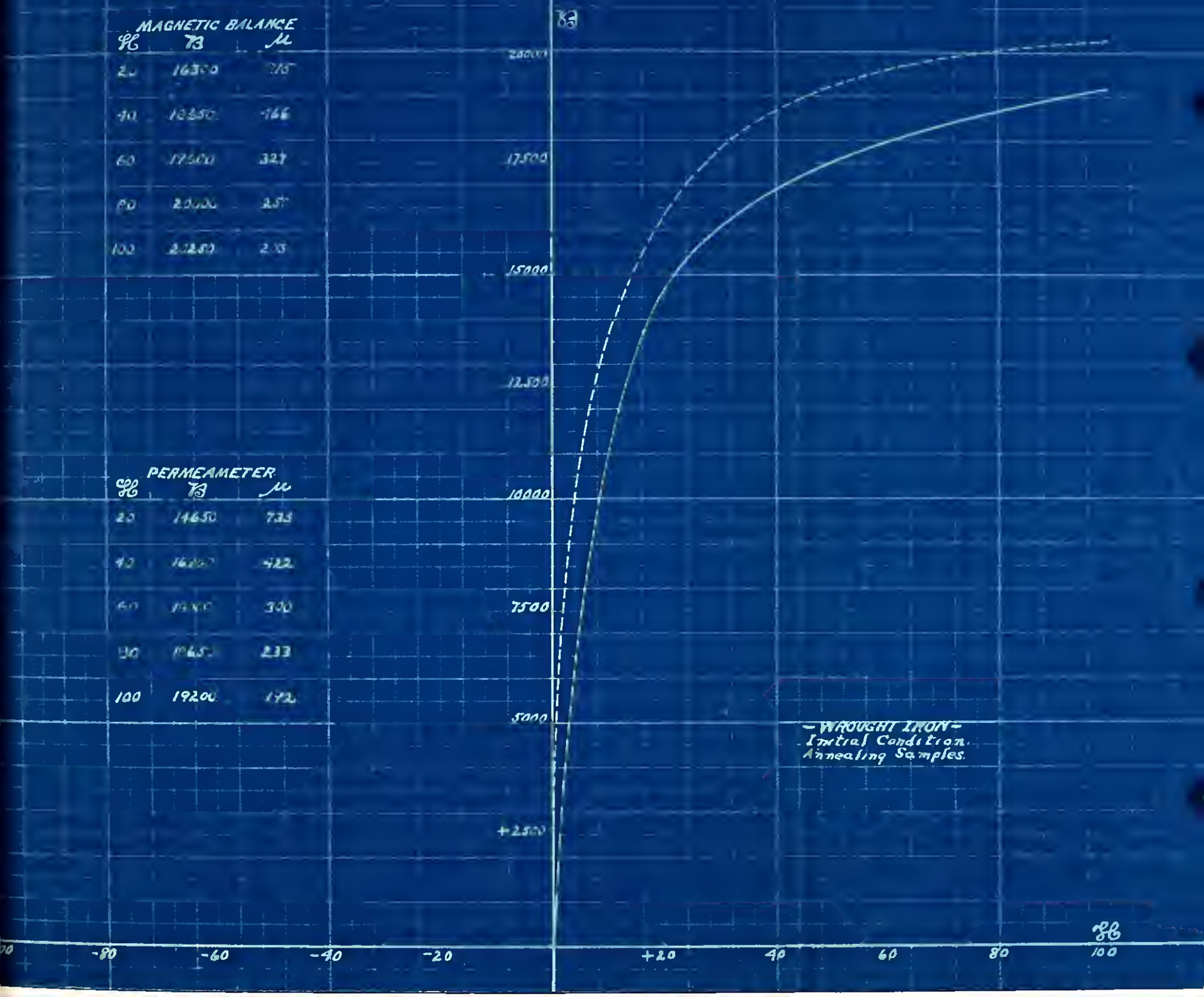
-80 -60 -40

MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	16300	815
40	10850	166
60	19500	327
80	20000	250
100	20250	203

PERMEAMETER

$\mathcal{H}$	$\mathcal{B}$	μ
20	14650	733
40	16850	422
60	19800	300
80	19650	233
100	19200	192



Data for B-H Curve of Wrought Iron (1) After Heating for Two Hours at 750°F.

Obtained on Magnetic Balance

B	H	B	H
20350	99.80	1000	-2.00
20000	79.60	-9200	-4.00
19650	60.00	-11900	-6.20
19300	40.00	-12750	-8.00
18850	30.00	-14100	-10.00
17700	20.80	-15850	-15.00
17250	15.00	-17000	-20.00
16000	10.00	-18250	-35.20
15400	8.00	-18820	-51.00
13650	4.00	-19450	-70.20
10050	0.0	-19950	-100.00

Data for B-H Curve of Wrought Iron (A) After Heating for Two Hours at 750 Degrees F.

Obtained from Esterline's Permeameter

B	B	h	H
122000	18900	1000	99.00
120500	18700	880	87.12
119000	18450	760	75.24
117500	18240	640	63.36
115500	17900	520	51.48
112000	17380	360	35.64
108500	16840	240	23.76
102000	15830	120	11.88
87500	13550	40	3.96
69500	10780	0	0.0
-41500	-6440	-80	-7.92
-79000	-12230	-120	-11.88
-91500	-14180	-160	-15.84
-97500	-15100	-200	-19.80
-100000	-15500	-240	-23.76
-104500	-16200	-360	-35.64
-111000	-17200	-520	-51.48
-114000	-17680	-680	-67.32
-117500	-18220	-880	-87.12
-119000	-18450	-1000	-99.00

Data for U-H Dueva [illegible] for [illegible] Sampling for

the Data [illegible]

(Millions [illegible])

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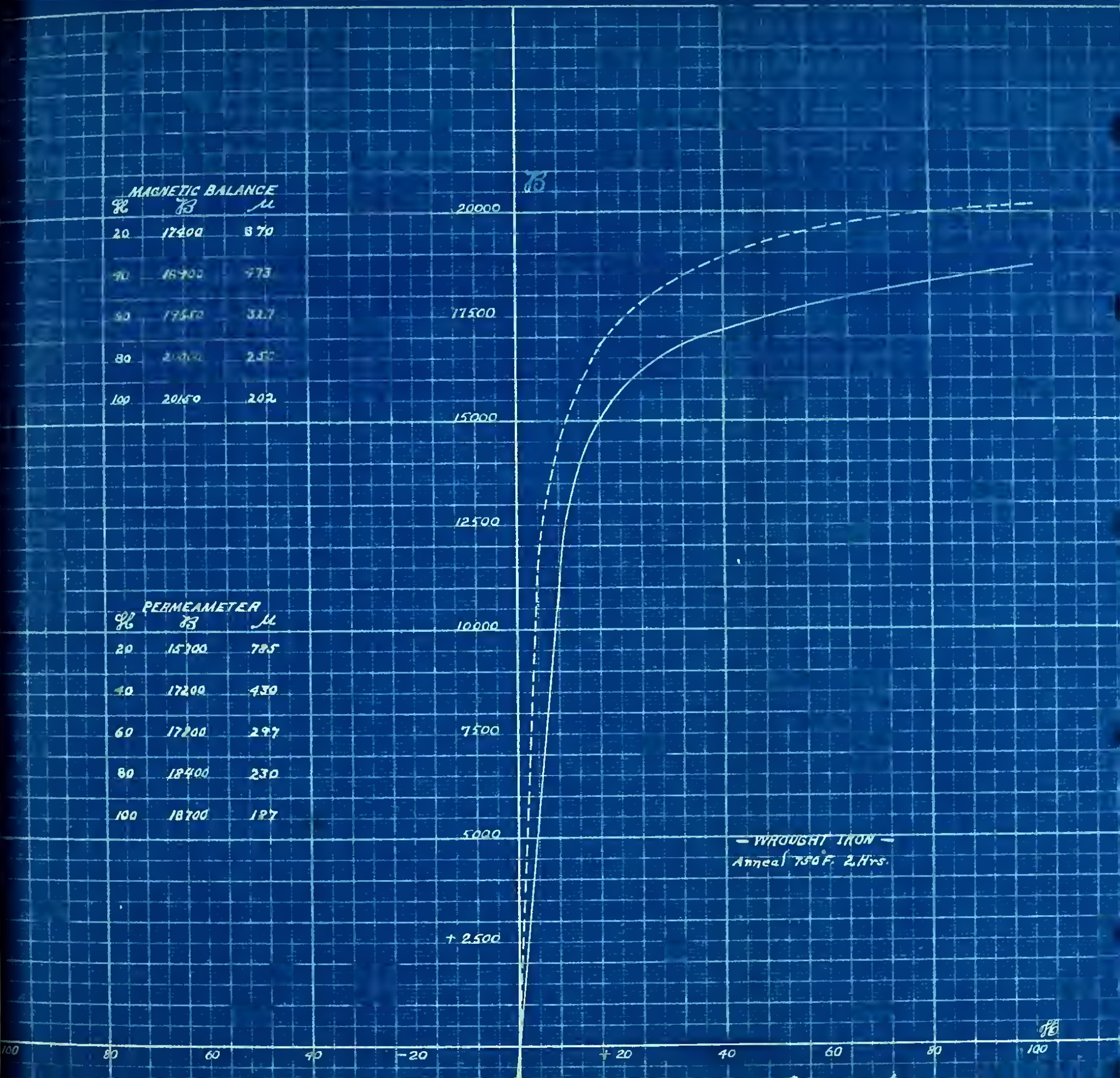
MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	17400	870
40	18700	473
60	17650	327
80	20000	250
100	20150	202

PERMEAMETER

$\mathcal{H}$	$\mathcal{B}$	μ
20	15700	785
40	17200	430
60	17800	297
80	18400	230
100	18700	187

80 60 40


MAGNETIC BALANCE
H B μ
20 17400 870
40 18900 473
60 17500 327
80 20100 250
100 20150 202
PERMEAMETER
H B μ
20 15700 785
40 17200 430
60 17200 297
80 18400 230
100 18700 187
B
20000
17500
15000
12500
10000
7500
5000
+2500
H
100
80
60
40
-20
+20
40
60
80
100
— WROUGHT IRON —
Anneal 750°F. 2 Hrs.

Data for B-H Curve of Wrought Iron (1) After Heating for Four Hours at 750°F.

Obtained on Magnetic Balance

B	H	B	H
19500	102.00	6500	-2.00
19180	80.00	-11000	-4.40
18850	58.80	-12300	-6.00
18450	40.00	-13850	-7.32
17650	18.00	-14800	-10.00
17250	14.00	-16200	-14.00
16350	9.80	-17150	-20.00
15450	6.20	-18050	-36.00
13000	2.00	-18750	-62.00
10800	0.0	-19100	-85.00
		-19400	-102.66

Data showing the

Data for B-H Curve Of Wrought Iron (A) After Heating for Fours Hours at 750°F.

Obtained on Esterline's Permeameter

b	B	h	H
119000	18450	1000	99.00
116000	18000	760	75.24
113000	17520	560	55.44
109000	16900	360	35.64
104500	16200	200	19.80
87500	13550	40	3.96
68000	10550	0	0.0
− 1000	− 155	-40	-3.96
− 53000	− 8220	-80	-7.92
− 82000	− 12700	-120	-11.88
− 92500	− 14350	-160	-15.84
− 98000	− 15200	-200	-19.80
− 103000	− 16000	-280	-27.72
− 107000	− 16600	-400	-39.60
− 110000	− 17050	-520	-51.48
− 113000	− 17550	-720	-71.28
− 116000	− 18000	-880	-87.12
− 117500	− 18250	-1000	-99.00

Data Showing the

Data for B-H Curve Of Wrought Iron (A) After Heating for Fours Hours at 750°F.

Obtained on Esterline's Permeameter

b	B	h	H
119000	18450	1000	99.00
116000	18000	760	75.24
113000	17520	560	55.44
109000	16900	360	35.64
104500	16200	200	19.80
87500	13550	40	3.96
68000	10550	0	0.0
− 1000	− 155	-40	-3.96
− 53000	− 8220	-80	-7.92
− 82000	− 12700	-120	-11.88
− 92500	− 14350	-160	-15.84
− 98000	− 15200	-200	-19.80
− 103000	− 16000	-280	-27.72
− 107000	− 16600	-400	-39.60
− 110000	− 17050	-520	-51.48
− 113000	− 17550	-720	-71.28
− 116000	− 18000	-880	-87.12
− 117500	− 18250	-1000	-99.00

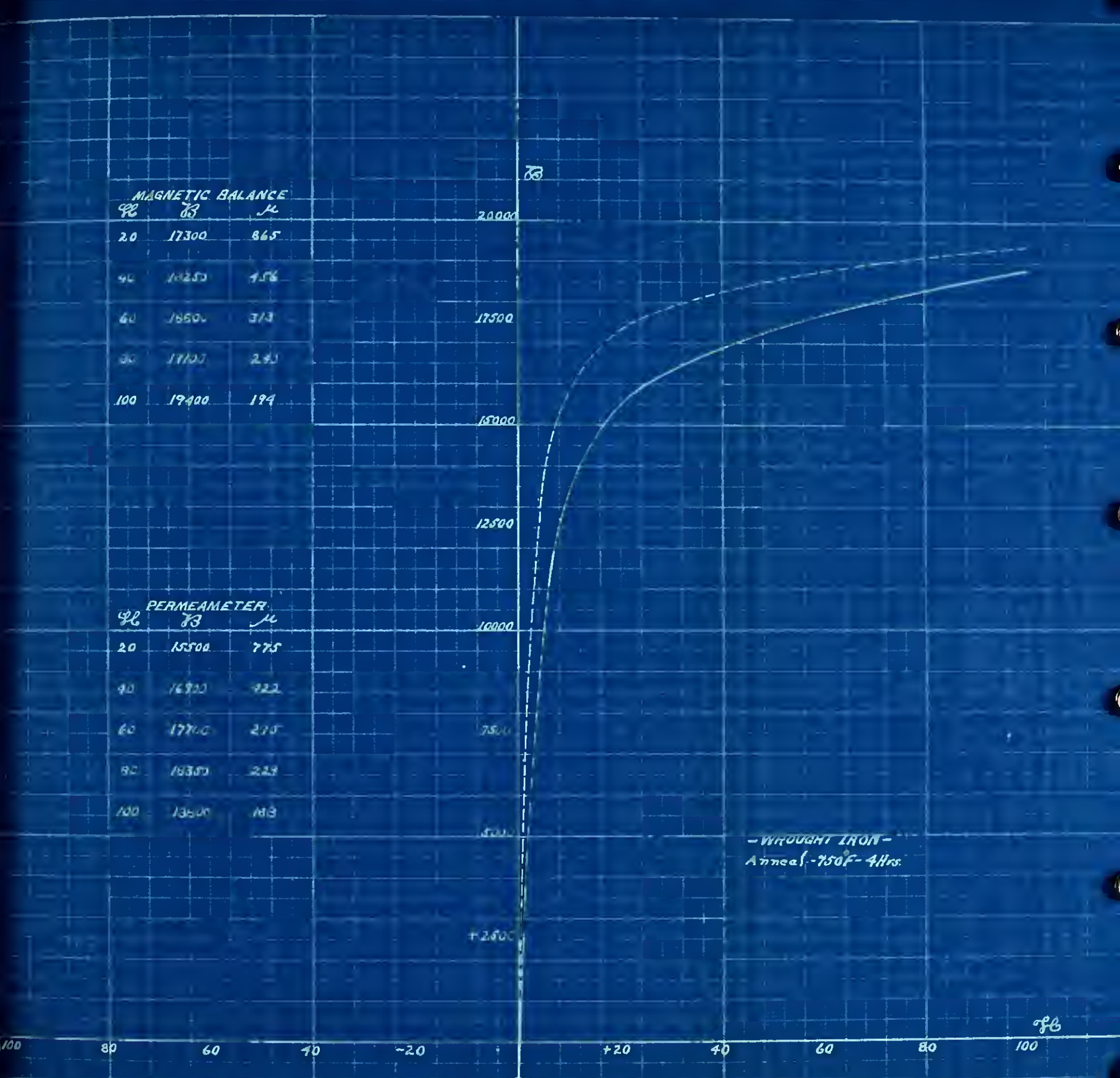
MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	17300	865
40	18250	456
60	18800	313
80	19100	240
100	19400	194

PERMEAMETER

$\mathcal{H}$	$\mathcal{B}$	μ
20	15500	775
40	16900	422
60	17700	295
80	18350	229
100	18800	188

0 80 60 40


MAGNETIC BALANCE
H B μ
20 17300 865
40 18250 456
60 18600 310
80 17100 213
100 19400 194
PERMEAMETER
H B μ
20 15500 775
40 16900 422
60 17700 295
80 18350 229
100 13600 136
B
20000
17500
15000
12500
10000
7500
5000
+2500
H
100
80
60
40
-20
+20
40
60
80
100
-WROUGHT IRON-
Anneal.-750°F-4Hrs.

Data for B-H Curve of Wrought Iron (1) After Heating for Two Hours at 1000°F.

Obtained on Magnetic Balance

B	H	B	H
19550	102.00	2900	-2.00
19320	80.00	-10800	-3.80
18950	59.00	-13600	-6.20
18450	40.00	-14500	-7.80
17800	22.00	-15600	-10.00
17540	15.00	-16700	-15.32
17000	10.00	-17100	-20.00
16250	5.80	-17850	-34.00
13500	2.00	-18200	-50.00
10600	0.0	-18600	-70.20
		-18800	-87.20
		-19050	-101.80

Data for B-H Curve of Wrought Iron (A) After Heating for Two Hours at 1000°F.

Obtained on Esterline's Permeameter

b	B	h	H
133500	20700	1000	99.00
131000	20300	800	79.20
129000	20000	600	59.40
128000	19850	400	39.60
123500	19150	200	19.80
119000	18450	80	7.92
104000	16150	00	0.0
-6500	-1005	-40	-3.96
-101000	-15650	-80	-7.92
-113000	-17550	-120	-11.88
-117500	-18200	-160	-15.84
-122500	-19000	-240	-23.76
-126500	-19650	-360	-35.64
-132000	-20500	-520	-51.48
-132500	-20550	-600	-59.40
-136000	-21100	-800	-79.20
-138000	-21400	-1000	-99.00

MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	17400	870
40	18200	455
60	18700	311
80	19000	237
100	19300	193

PERMEAMETER

$\mathcal{H}$	$\mathcal{B}$	μ
20	18900	945
40	19800	495
60	20300	340
80	20750	259
100	21100	211

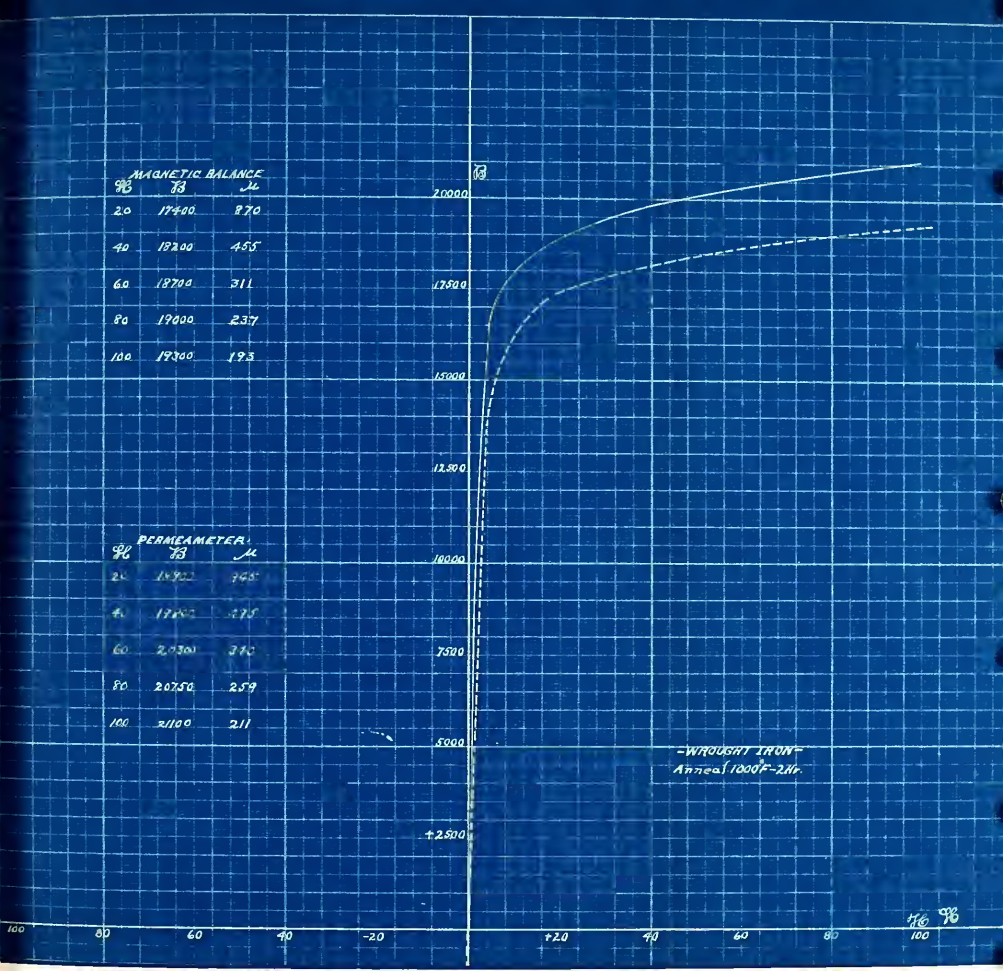
80 60 40

MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	17400	870
40	18200	455
60	18700	311
80	19000	237
100	19300	193

PERMEAMETER

$\mathcal{H}$	$\mathcal{B}$	μ
20	16900	845
40	17600	440
60	20300	340
80	20750	259
100	21100	211



Data for B-H Curve of Wrought Iron (1) After Heating for Four Hours at 1000°F.

Obtained on Magnetic Balance

B	H	B	H
19200	101.40	-1800	-2.00
18800	69.00	-9650	-3.80
18150	40.00	-12650	-5.60
17450	16.00	-14250	-7.80
17125	10.00	-15400	-10.00
16040	5.80	-16100	-14.00
13350	2.00	-16800	-20.00
10400	0.0	-17750	-40.00
		-18450	-71.00
		-19150	-101.40

Data for B-H Curve of Wrought Iron (A) After Heating for Four Hours at 1000°F.

Obtained on Esterline's Permeameter

b	B	h	H
137000	21150	1000	99.00
136000	21100	800	79.20
131000	20300	600	59.40
127000	19700	400	39.60
125000	19400	320	31.68
123000	19100	240	23.76
119000	18450	120	11.88
113000	17540	40	3.96
98000	15200	00	0.0
-3000	-465	-40	-3.96
-103500	-16050	-120	-11.88
-116500	-18050	-200	-19.80
-117500	-18200	-240	-23.76
-127000	-19700	-320	-31.68
-130000	-20150	-400	-39.60
-134000	-20800	-600	-59.40
-137000	-21300	-800	-79.20
-141000	-21900	-1000	-99.00

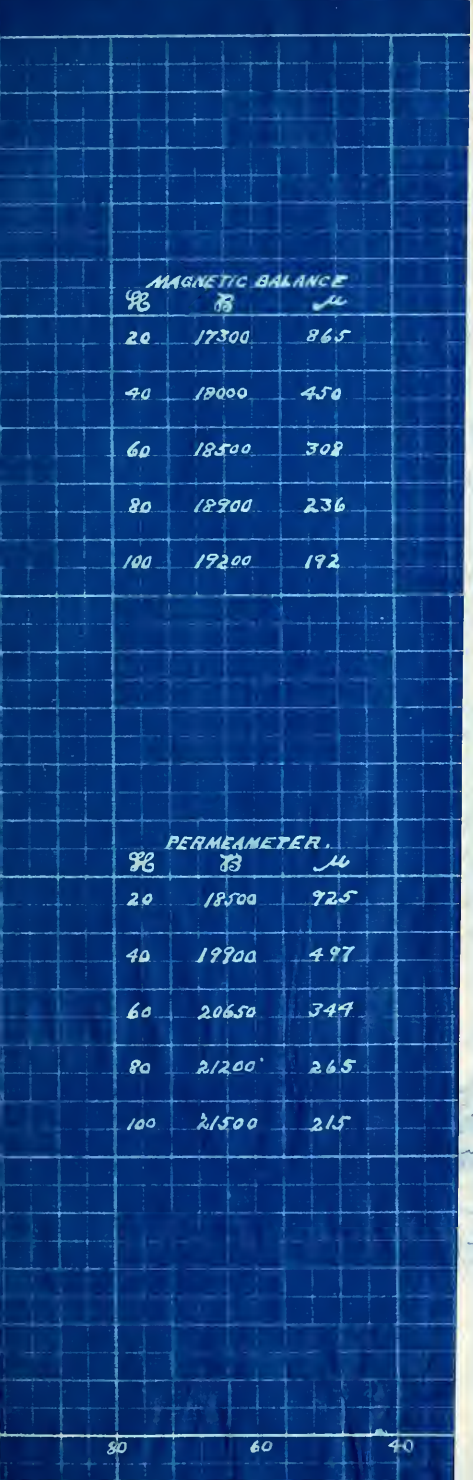
C

MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	17300	865
40	19000	450
60	18500	308
80	18900	236
100	19200	192

PERMEAMETER.

$\mathcal{H}$	$\mathcal{B}$	μ
20	18500	925
40	19900	497
60	20650	344
80	21200	265
100	21500	215



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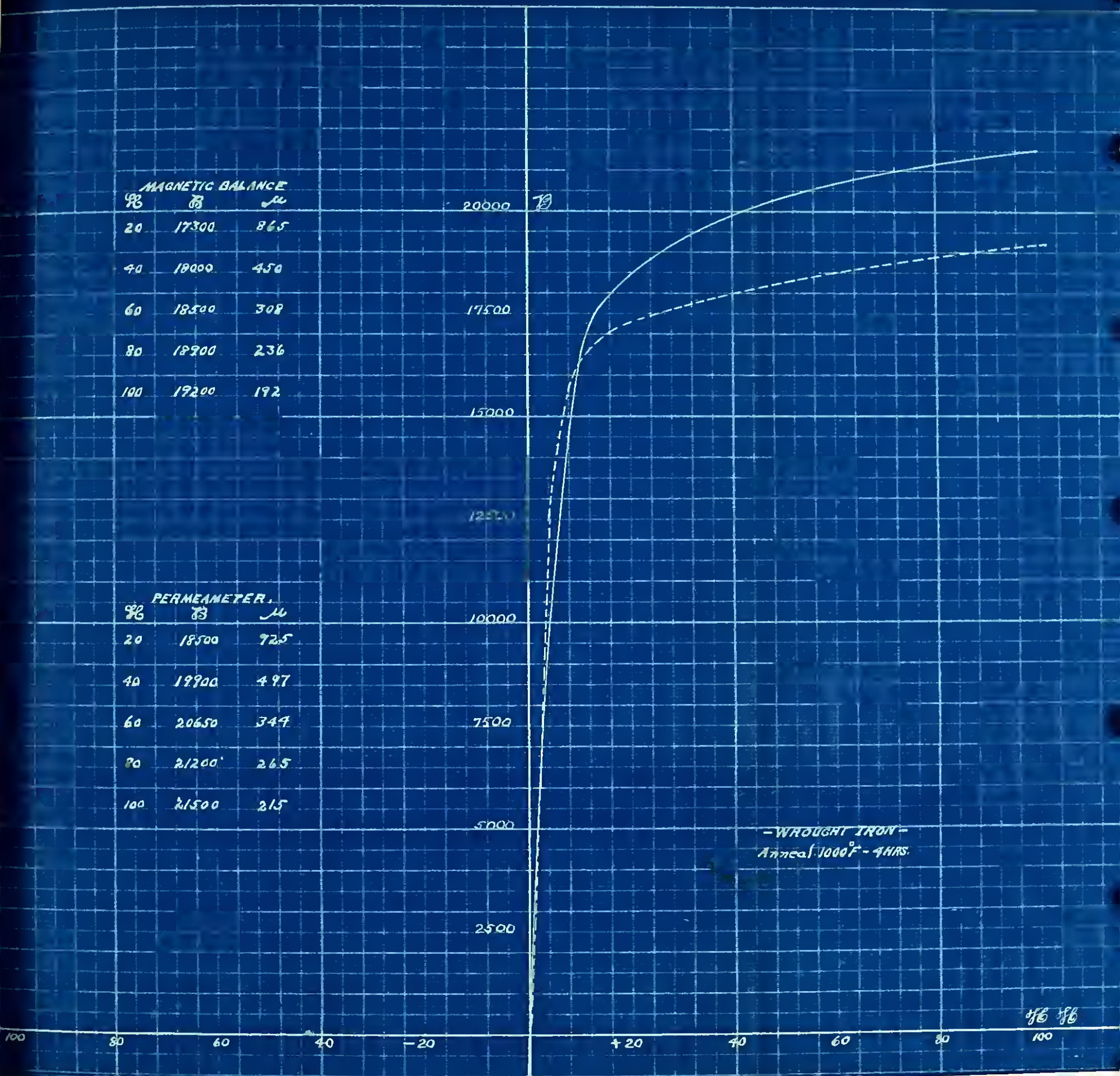
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	17300	865
40	18000	450
60	18500	308
80	18900	236
100	19200	192

PERMEAMETER.

$\mathcal{H}$	$\mathcal{B}$	μ
20	18500	925
40	19900	497
60	20650	344
80	21200	265
100	21500	215



Data for B-H Curve of Wrought Iron (1) After Heating for Two Hours at 1800°F.

Obtained on Magnetic Balance

B	H	B	H
19050	99.40	3500	-2.00
18750	68.00	-12500	-4.66
18250	39.80	-13500	-6.00
17800	20.00	-14500	-7.80
17400	10.00	-15400	-10.00
16650	6.00	-16350	-14.00
15050	3.00	-17000	-20.00
10500	0.0	-17450	-32.00
		-18050	-50.20
		-18300	-71.20
		-18700	-99.40

[illegible]

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		
[illegible]	[illegible]		
[illegible]	[illegible]		

Data for B-H Curve of Wrought Iron (A) After Heating for Two Hours at 1800°F.

Obtained on Esterline's Permeameter

b	B	h	H
147000	22800	1000	99.00
142500	22100	800	79.20
140000	21700	600	59.40
136000	21100	400	39.60
130000	20200	200	19.80
123000	19050	80	7.92
102500	15900	0	0.0
-3000	-465	-40	-3.96
-92000	-14250	-80	-7.92
-107000	-16600	-120	-11.88
-113000	-17500	-160	-15.84
-119000	-18450	-240	-23.76
-124000	-19240	-360	-35.64
-128000	-19850	-520	-51.48
-133000	-20650	-680	-67.32
-136000	-21100	-880	-87.12
-138500	-21500	-1000	-99.00

MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	17300	865
40	18000	450
60	18400	307
80	18700	234
100	18900	189

PERMEAMETER

$\mathcal{H}$	$\mathcal{B}$	μ
20	19250	963
40	20150	504
60	20900	350
80	21600	270
100	22200	222

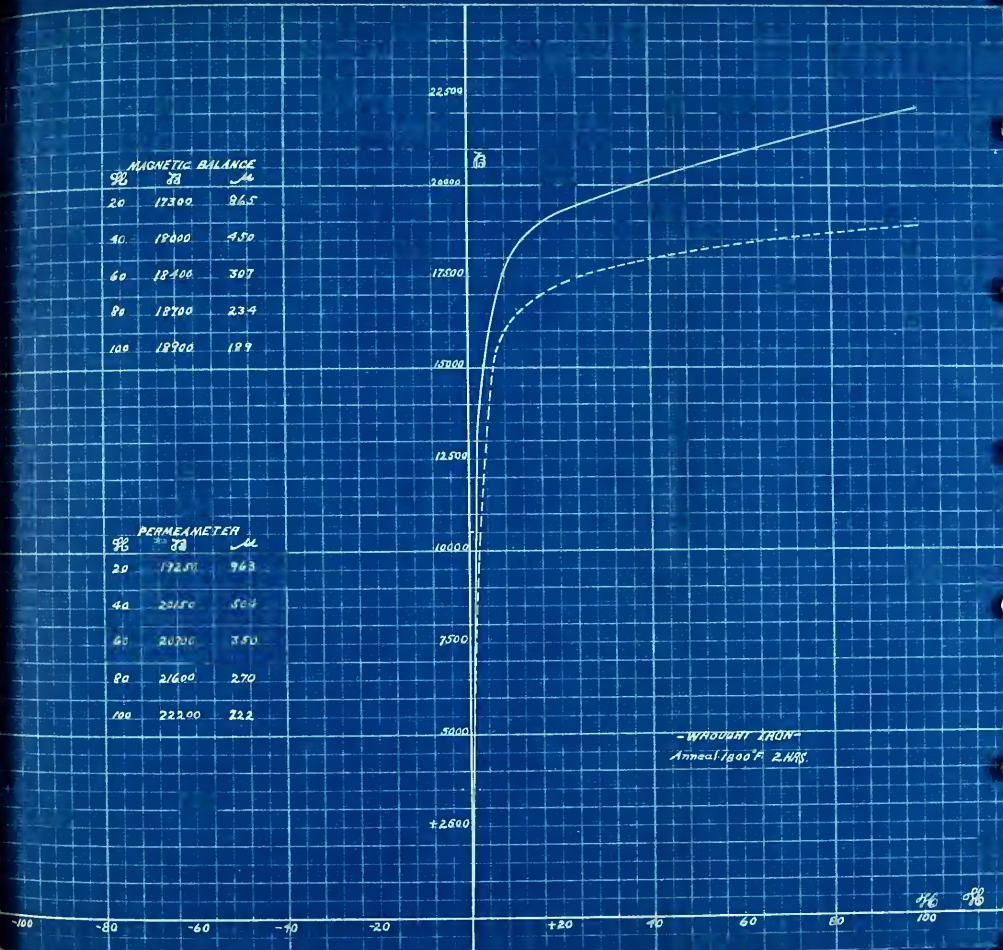
-80 -60 -40

MAGNETIC BALANCE

%	B	μ
20	17300	865
40	18000	450
60	18400	307
80	18700	234
100	18900	189

PERMEAMETER

%	B	μ
20	19250	963
40	20150	504
60	20700	350
80	21600	270
100	22200	222



Data for B-H Curve of Wrought Iron (1) After Heating for Four Hours at 1800°F.

Obtained on Magnetic Balance

B	H	B	H
20200	100.20	4300	-2.00
19850	70.80	-11500	-4.00
19120	39.40	-13850	-6.00
18620	20.00	-15400	-8.00
18000	10.20	-16300	-10.20
16500	6.00	-17350	-14.00
14250	2.20	-18000	-20.00
10800	0.0	-18450	-30.00
		-18950	-50.00
		-19400	-70.66
		-20100	-100.00

Data for B-H Curve of Wrought Iron (A) After Heating for Four Hours at 1800°F.

Obtained on Esterline's Permeameter

b	B	h	H
131000	20300	1000	99.00
128500	19950	800	79.20
125000	19400	600	59.40
121500	18850	400	39.60
118000	18300	200	19.80
114500	177500	80	7.92
98000	15200	00	0.0
-2000	-310	-40	-3.96
-90500	-14050	-80	-7.92
-100000	-15500	-120	-11.88
-109000	-16900	-200	-19.80
-113000	-17550	-320	-31.68
-117500	-18200	-480	-47.52
-119000	-18450	-640	-63.36
-124000	-19250	-840	-83.16
-125000	-19400	-1000	-99.00

Data for [illegible] Curve of Frequent Pen ( ) after Restoration

Four Hours at [illegible].

Obtained on Sterling's Manometer

b	b	b	b
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
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-[illegible]	-[illegible]	-[illegible]	[illegible]
-[illegible]	-[illegible]	-[illegible]	[illegible]

MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	18400	920
40	19000	475
60	19500	325
80	19800	247
100	20100	201

PERMEAMETER

$\mathcal{H}$	$\mathcal{B}$	μ
20	17600	880
40	18500	460
60	19200	320
80	19500	244
100	19900	199

Data for each Curve of Pressure from [illegible] after [illegible]

Year Ended [illegible]

Obtained on [illegible]

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
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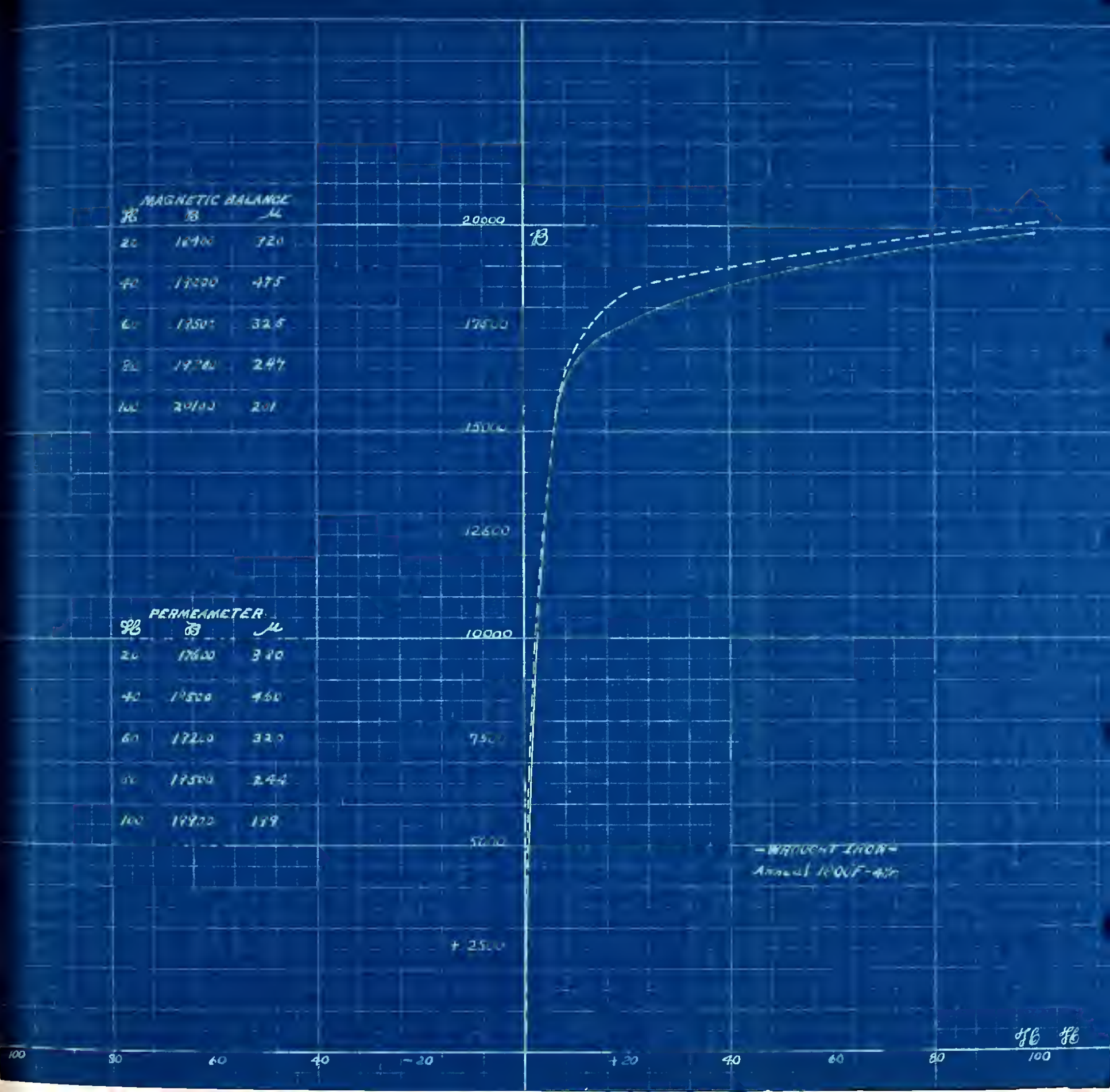
[illegible]	[illegible]	[illegible]	[illegible]


MAGNETIC BALANCE
H B μ
20 16400 720
40 19000 475
60 19500 325
80 19900 247
100 20100 201
PERMEAMETER
H B μ
20 17600 880
40 19500 460
60 19200 320
80 19500 244
100 19900 199
20000
17500
15000
12500
10000
7500
5000
+2500
B
-WROUGHT IRON-
Annual 1800F-4hr
100
80
60
40
-20
+20
40
60
80
100
H H

Data for B-H CURVE of Soft Steel in Initial Condition.

Obtained on Magnetic Balance

B	H	B	H
19200	100.00	7950	-2.00
19125	80.00	- 3800	-4.00
18700	60.00	- 9500	-6.00
18600	50.00	-12750	-8.20
18350	40.00	-13400	-10.00
18000	30.00	-15350	-14.00
17700	18.00	-16625	-20.00
17650	14.00	-17750	-30.00
17250	10.00	-18050	-40.00
16900	8.20	-18325	-50.66
16500	6.00	-18600	-60.00
16200	4.50	-18950	-81.00
15250	2.00	-19200	-100.00
13150	0.0		

Data for B-H Curve of Soft Steel inInitial Condition.

Obtained on Esterline's Permeameter

b	B	h	H
112000	17350	1000	99.00
111000	17200	880	87.12
108000	16750	800	79.20
105000	16300	640	63.36
104000	16150	520	51.48
98500	15280	360	35.64
97500	15100	320	31.68
95000	14730	240	23.76
94000	14570	200	19.80
91000	14100	160	15.84
89500	13850	120	11.88
85000	13150	80	7.92
80000	12400	40	3.96
69000	10700	0	0.0
-15000	-2330	-40	-3.96
-19500	-3020	-80	-7.92
-63000	-9775	-120	-11.88
-74000	-11450	-160	-15.84
-82000	-12700	-200	-19.80
-88000	-13650	-240	-23.76
-94000	-14550	-320	-31.68
-95000	-14740	-360	-35.64
-100000	-15500	-520	-51.48
-105000	-16300	-640	-63.36
-110000	-17050	-800	-79.20
-112000	-17350	-880	-87.12
-114000	-17700	-1000	-99.00

MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	17100	855
40	18200	455
60	18600	310
80	19000	240
100	19200	192

PERMEAMETER

$\mathcal{H}$	$\mathcal{B}$	μ
20	13800	690
40	15300	382
60	16300	271
80	17000	212
100	17600	176

80 60 40

[illegible]

[illegible] (Adapted on [illegible])

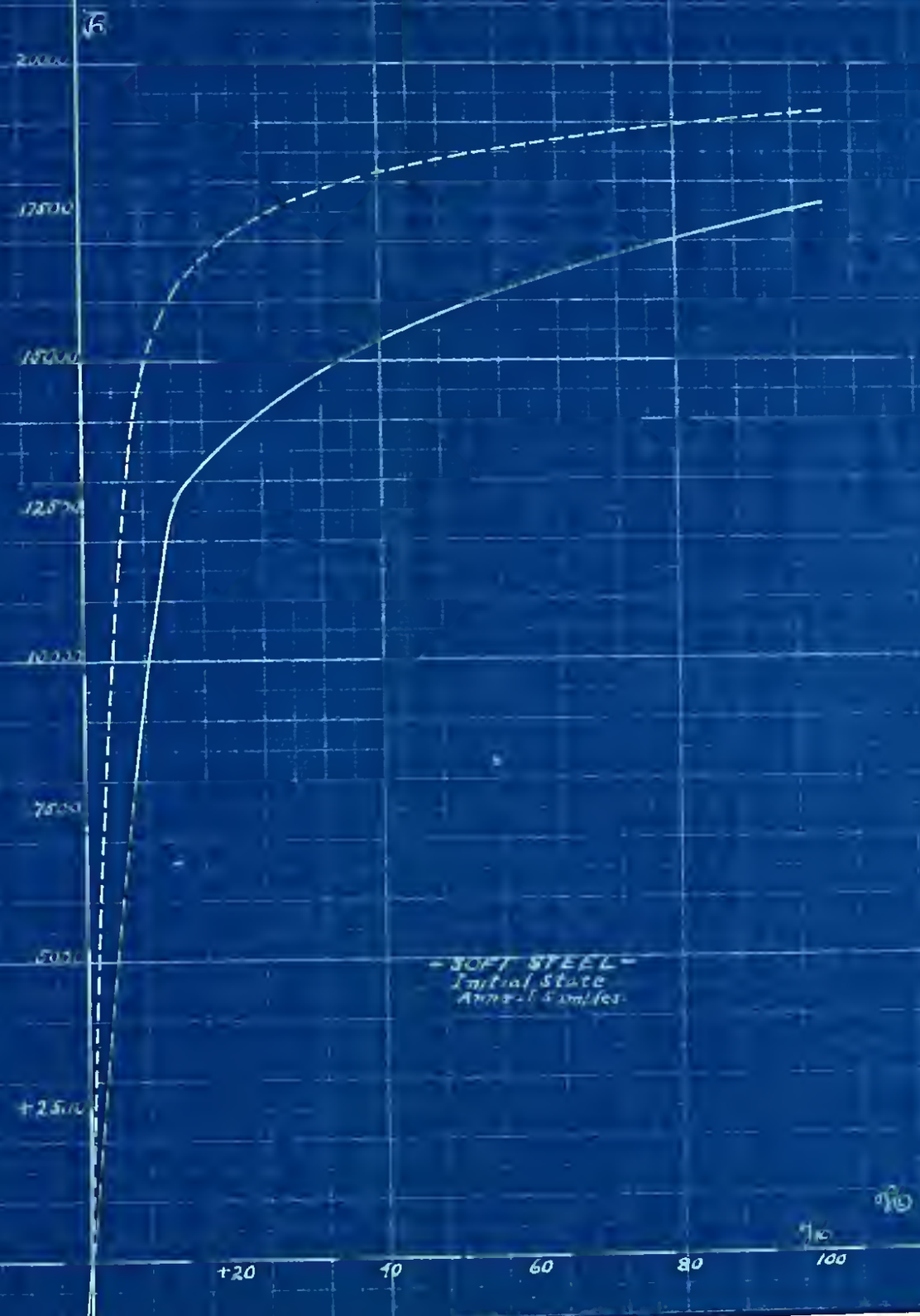
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	17100	855
40	17200	455
60	17600	310
80	17000	240
100	17200	172

PERMEAMETER

$\mathcal{H}$	$\mathcal{B}$	μ
20	13800	690
40	15300	382
60	16300	271
80	17000	212
100	17600	176



Data for B-H CUrve of Soft Steel(2) After Heating for Two Hours at 750°F.

Obtained on Magnetic Balance

B	H	B	H
19050	100.00	9600	-2.00
18850	80.00	600	-4.00
18650	60.00	-3450	-6.00
18350	40.00	-7000	-6.80
18000	30.00	-8800	-8.00
17100	16.60	-11300	-10.00
16650	12.00	-12100	-12.00
16250	10.20	-13650	-16.00
15300	6.00	-14950	-20.00
14800	4.00	-15750	-24.00
14150	2.20	-16950	-30.00
12600	0.0	-17250	-40.00
		-18200	-60.20
		-18750	-80.66
		-19150	-100.66

Data for B-H Curve of Soft Steel (B) After Heating for Two Hours at 750°F.

Obtained on Esterline's Permeameter

b	B	h	H
121000	18750	1000	99.00
117000	18150	800	79.20
116000	18000	640	63.36
112000	17400	480	47.52
108500	16850	320	31.68
103000	16000	200	19.80
94000	14550	80	7.92
89500	13900	40	3.96
82500	12750	0	0.0
-21000	-3250	-80	-7.92
-65000	-10050	-120	-11.88
-82000	-12700	-160	-15.84
-90000	-13950	-200	-19.80
-95000	-14730	-240	-23.76
-99000	-15350	-280	-27.72
-105500	-16350	-400	-39.60
-114000	-17700	-600	-59.40
-117000	-18150	-800	-79.20
-120500	-18700	-1000	-99.00

Data for B-H Curve of Left Steel (B) after [illegible]

[illegible]

Obtained by [illegible]

D	[illegible]	[illegible]	[illegible]
121000	13700	1000	[illegible]
117000	[illegible]	[illegible]	[illegible]
116000	13900	[illegible]	[illegible]
112000	13900	[illegible]	[illegible]
108000	13900	[illegible]	[illegible]
100000	13900	[illegible]	[illegible]
94000	14500	[illegible]	[illegible]
89000	[illegible]	[illegible]	[illegible]
82500	15750	[illegible]	[illegible]
-71000	-7950	-[illegible]	[illegible]
-65000	-10000	-[illegible]	[illegible]
-23000	-13700	-100	[illegible]
-[illegible]	-13900	-[illegible]	[illegible]
-[illegible]	-14700	-[illegible]	[illegible]
-[illegible]	-[illegible]	-[illegible]	[illegible]
-[illegible]	-15700	-[illegible]	[illegible]
-[illegible]	-[illegible]	-[illegible]	[illegible]
-117000	-[illegible]	-[illegible]	[illegible]
-[illegible]	-[illegible]	-[illegible]	[illegible]

MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	16300	815
40	17700	442
60	18350	306
80	18750	234
100	19000	190

PERMEAMETER

$\mathcal{H}$	$\mathcal{B}$	μ
20	15000	750
40	16700	417
60	17500	292
80	18150	227
100	18700	187

[illegible]

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
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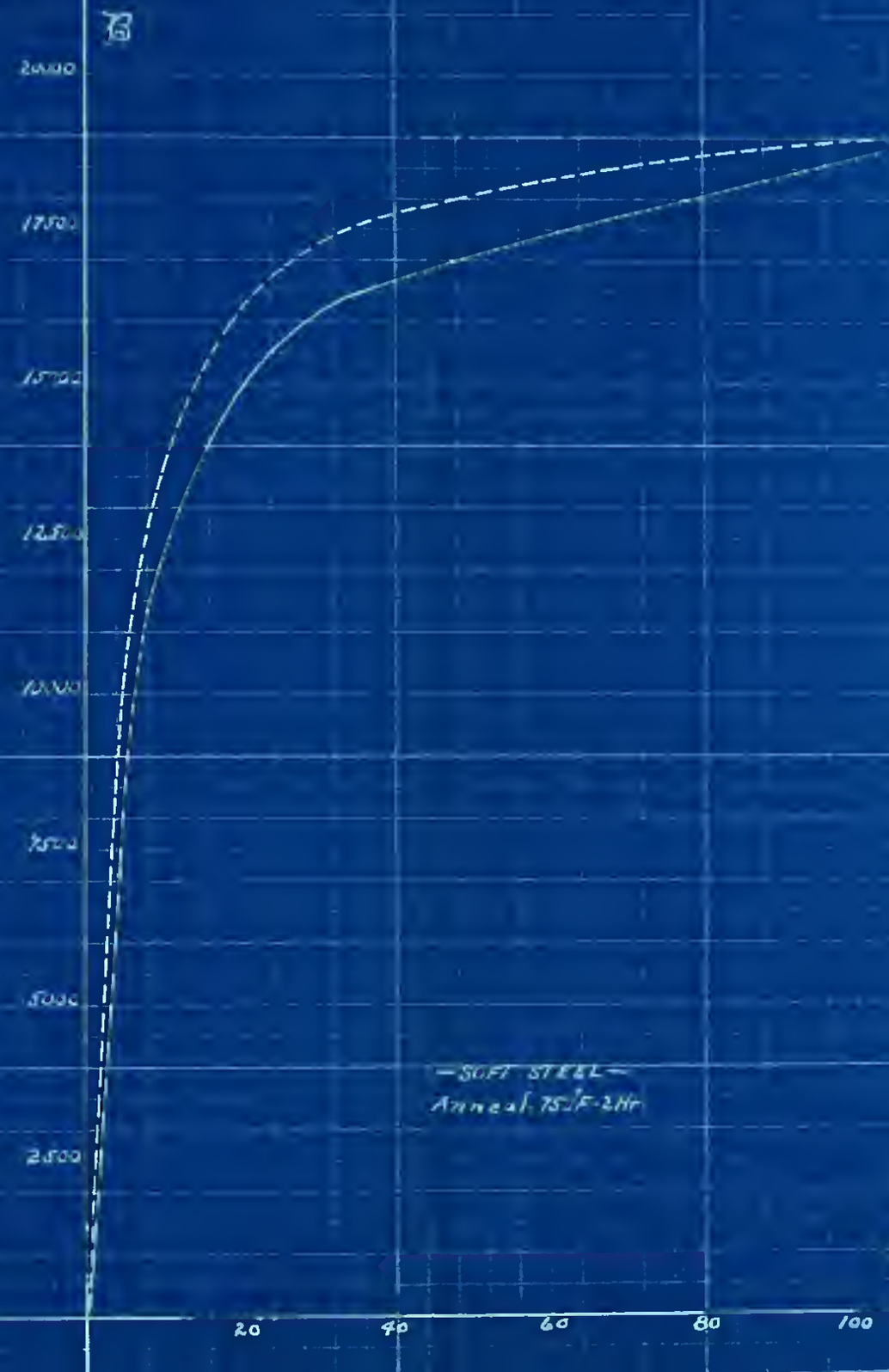
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	16300	815
40	17700	442
60	16350	306
80	15250	234
100	17000	172

PERMEAMETER

$\mathcal{H}$	$\mathcal{B}$	μ
20	15000	750
40	16700	417
60	17500	292
80	18150	227
100	15700	157



Data for B-H Curve of SOFT STEEL (2) After Heating for Four Hours at 750°F.

Obtained on Magnetic Balance

B	H	B	H
19600	100.80	+3100	-4.80
19580	90.60	-7300	-6.00
19300	70.00	-8900	-7.00
18800	50.00	-10150	-8.00
18420	40.00	-12350	-10.00
18040	30.00	-13620	-12.00
17100	16.00	-16500	-20.00
16750	12.00	-17800	-36.00
16450	10.00	-18600	-50.00
15900	7.00	-19150	-70.00
15680	6.00	-19400	-90.00
15550	4.80	-19600	-100.00
12550	0.0		

Data for B-H Curve of Soft Steel (B) After Heating for Four Hours at 750°F.

Obtained on Esterline's Permeameter

b	B	h	H
128000	19850	1000	99.00
126500	19640	880	87.12
124500	19300	720	71.28
120000	18600	520	51.48
118000	18300	320	31.68
113500	17600	240	23.76
108500	16850	160	15.84
103000	15950	80	7.92
98000	15200	40	3.96
90500	14000	0	0.0
-20000	-3110	-80	- 7.92
-72000	-11150	-120	-11.88
-84500	-13100	-160	-15.84
-93000	-14400	-200	-19.80
-99500	-15450	-240	-23.76
-105500	-16350	-360	-35.64
-114000	-18450	-480	-47.52
-115500	-17950	-600	-59.40
-120500	-18700	-800	-79.20
-125000	-19400	-1000	-99.00

Data for a-1 Query of data [illegible] (B) after [illegible] [illegible]

[illegible] at [illegible].

[illegible] [illegible] [illegible] [illegible]

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

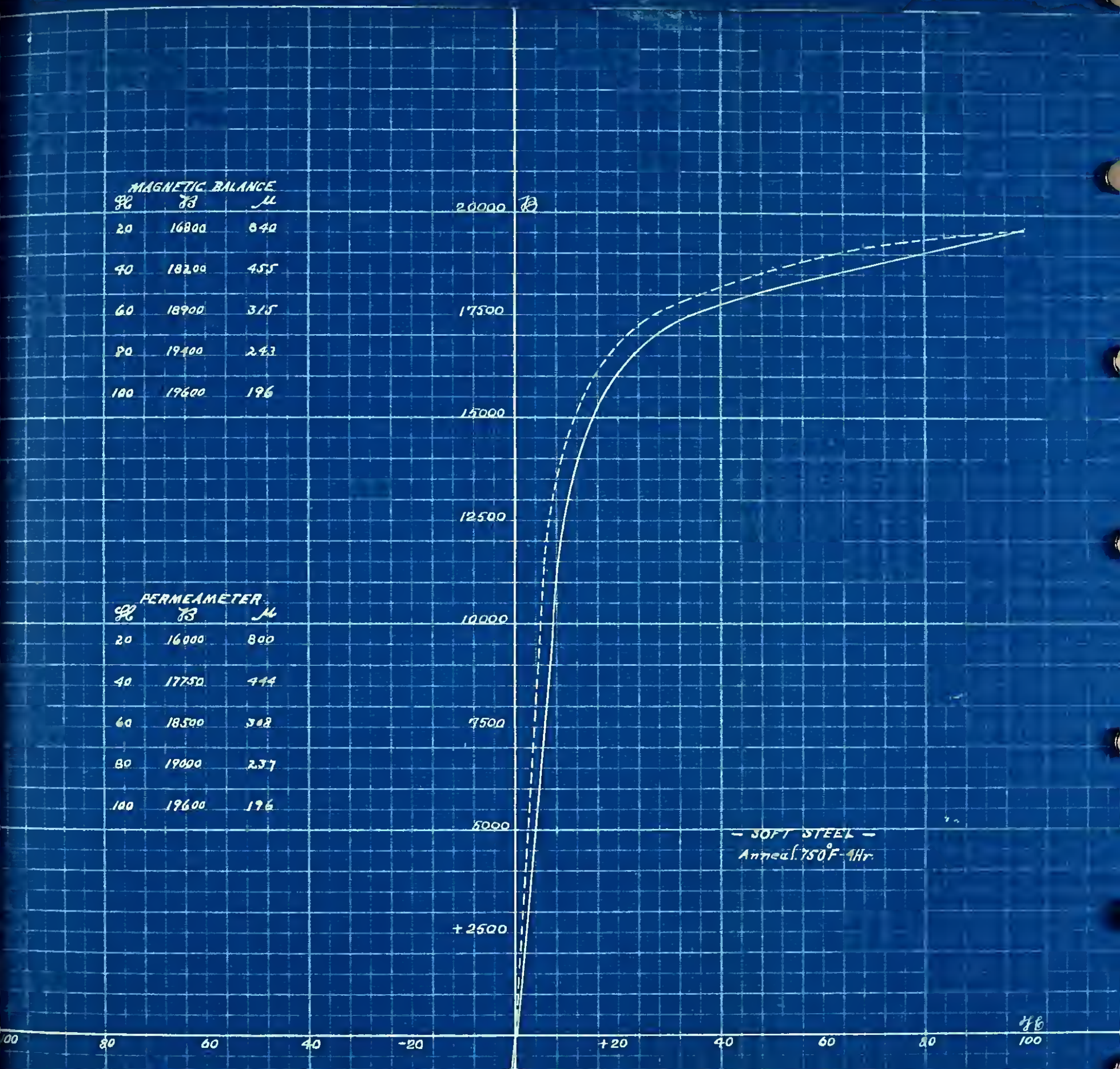
MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	16800	840
40	18200	455
60	18900	315
80	19400	243
100	19600	196

PERMEAMETER

$\mathcal{H}$	$\mathcal{B}$	μ
20	16000	800
40	17750	444
60	18500	308
80	19000	237
100	19600	196

80 60 40


MAGNETIC BALANCE
H B μ
20 16800 840
40 18200 455
60 18900 315
80 19400 243
100 19600 196
PERMEAMETER
H B μ
20 16000 800
40 17750 444
60 18500 308
80 19000 237
100 19600 196
20000 B
17500
15000
12500
10000
7500
5000
+2500
100 80 60 40 -20 +20 40 60 80 100
H
— SOFT STEEL —
Anneal. 750°F-1Hr.

Data for B-H Curve of Soft Steel (2) After Heating for Two Hours at 1000°F.

Obtained on Magnetic Balance

B	H	B	H
19600	102.66	9450	-2.00
19250	72.00	2400	-4.00
18950	49.80	-9000	-6.00
18450	29.80	-12300	-8.00
18400	20.00	-14200	-10.00
17500	10.00	-16100	-15.00
17000	6.00	-17000	-20.00
15700	2.00	-17900	-30.00
14050	0.0	-18050	-40.00
		-18600	-61.60
		-19050	-80.00
		-19300	-102.20

Data for B-H Curve of Soft Steel (B) After Heating For Two Hours at 1000°F.

Obtained on Esterline's PErmeameter

b	B	h	H
140000	21700	1000	99.00
139000	21500	800	79.20
136000	21040	600	59.40
132500	20550	400	39.60
128000	19850	200	19.80
122500	19000	80	7.92
119000	18450	40	3.96
113000	17550	0	0.0
-45000	-6980	-80	-7.92
-118000	-18300	-200	-19.80
-130000	-20200	-400	-39.60
-134000	-20800	-600	-59.40
-139000	-21550	-800	-79.20
-141500	-21900	-1000	-99.00

MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	17600	880
40	18500	462
60	18900	315
80	19200	240
100	19400	194

PERMEAMETER

$\mathcal{H}$	$\mathcal{B}$	μ
20	19100	955
40	20400	510
60	21100	352
80	21500	270
100	21800	218

80 60 40

Data for [illegible] Study [illegible] (M) [illegible]

Group [illegible].

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
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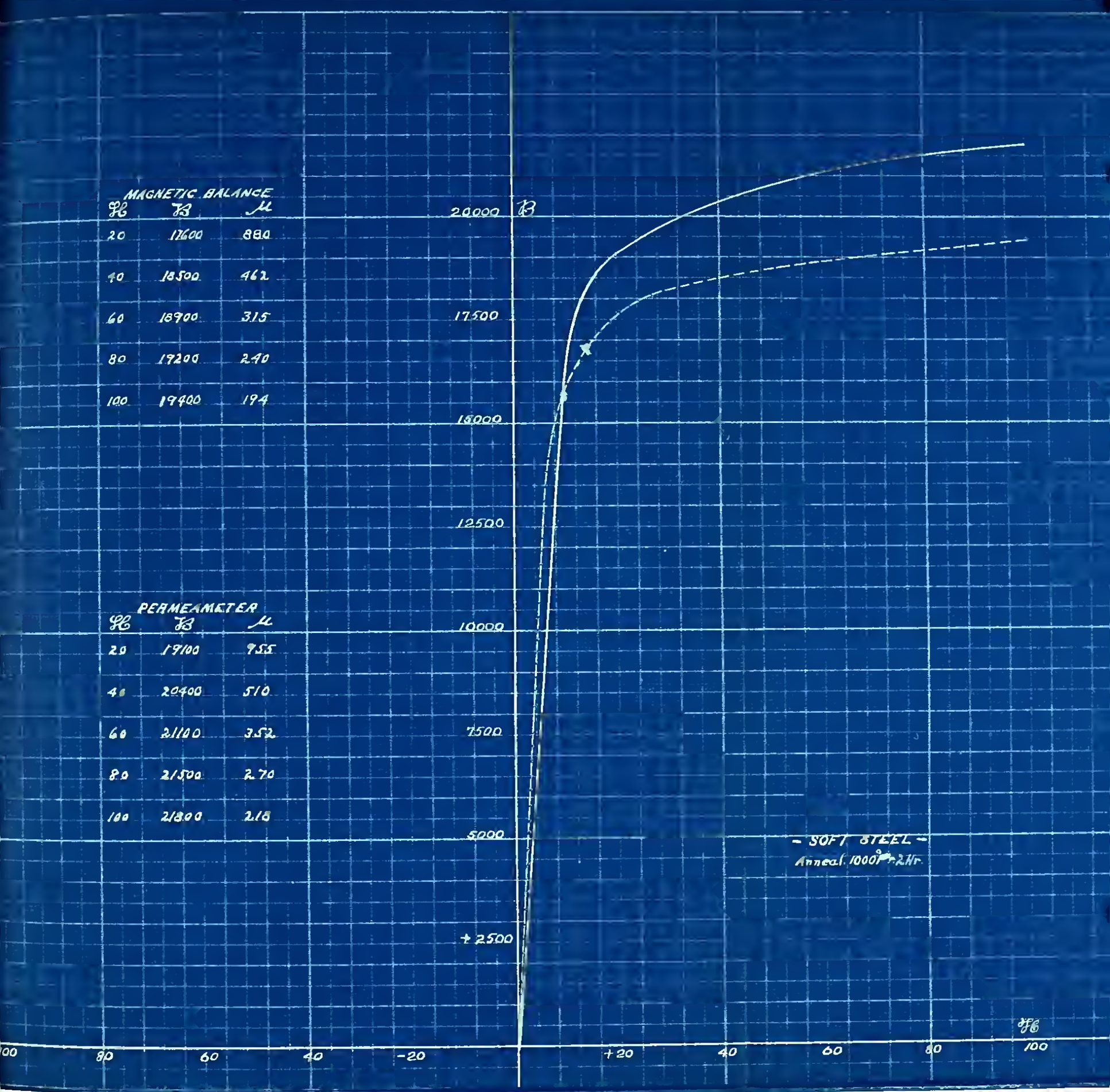
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	17600	880
40	18500	462
60	18900	315
80	19200	240
100	19400	194

PERMEAMETER

$\mathcal{H}$	$\mathcal{B}$	μ
20	19100	955
40	20400	510
60	21100	352
80	21500	270
100	21800	218



Data for B-H Curve of Soft Steel (2) After Heating for Four Hours at 1000°F.

Obtained on Magnetic Balance

B	H	B	H
19700	100.00	10400	-2.00
19400	69.32	0	-2.50
19100	50.00	-7350	-5.60
18450	24.80	-10600	-7.20
18000	14.80	-11100	-8.00
17700	10.00	-13000	-10.00
17250	6.20	-14100	-12.00
16000	2.00	-15500	-16.00
14400	0.0	-16200	-20.00
		-17625	-30.00
		-18300	-50.66
		-19100	-78.20
		-19600	-102.20

[illegible]

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]		
[illegible]	[illegible]		
[illegible]	[illegible]		
[illegible]	[illegible]		

Data for B-H Curve of Soft Steel(B) After Heating for FOUR Hours at 1000°F.

Obtained on Esterline's Permeameter

b	B	h	H
130000	20200	1000	99.00
127000	19700	800	79.20
124000	19250	600	59.40
120500	18700	400	39.60
118000	18300	240	23.76
114500	17750	120	11.88
111000	17250	40	3.96
105000	16300	0	0.0
-35000	-5425	-80	-7.92
-91500	-14200	-120	-11.88
-100000	-15500	-160	-15.84
-109000	-16900	-240	-23.76
-112500	-17450	-320	-31.68
-118500	-18400	-440	-43.56
-123500	-19150	-600	-59.40
-126500	-19600	-800	-79.20
-131000	-20300	-1000	-99.00

MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	17300	865
40	18500	460
60	19200	316
80	19400	242
100	19600	196

PERMEAMETER

$\mathcal{H}$	$\mathcal{B}$	μ
20	17300	865
40	18500	460
60	19200	320
80	19700	246
100	20100	201

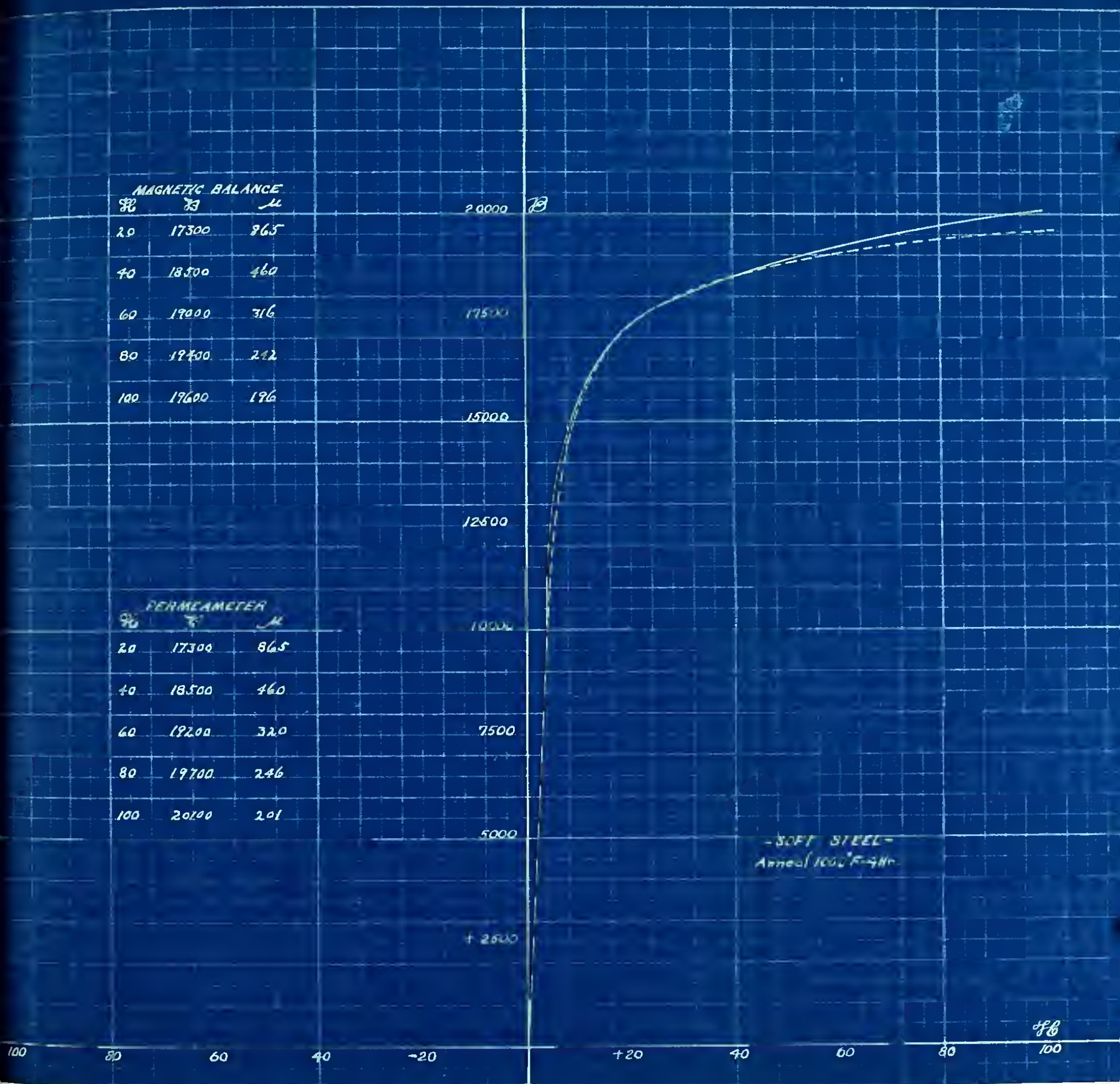
80 60 40

MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	17300	865
40	18500	460
60	19000	316
80	19400	242
100	19600	196

PERMEAMETER

$\mathcal{H}$	$\mathcal{B}$	μ
20	17300	865
40	18500	460
60	19200	320
80	19700	246
100	20100	201



Data for B-H Curve of Soft Steel (2) After Heating for Two Hours at 1800°F.

Obtained on Magnetic Balance

B	H	B	H
19150	101.00	2200	-2.00
18700	68.40	-3500	-3.80
18150	40.00	-12000	-6.00
17450	20.00	-12450	-8.00
16200	10.00	-12700	-10.00
13000	3.00	-14700	-14.00
10500	0.0	-16000	-20.00
		-17350	-30.00
		-17630	-40.00
		-18500	-71.00
		-19200	-101.00

Data for B-H Curve of Soft Steel (B) After Heating for Two Hours at 1800°F.

Obtained onEsterline's Permeameter

b	B	h	H
143500	22250	1000	99.00
140500	21800	800	79.20
137000	21300	600	59.40
132000	20500	400	39.60
121500	18800	200	19.80
114000	17700	120	11.88
98500	15250	40	3.96
79000	12250	0	0.0
-32000	-4960	-80	-7.92
-71000	-11000	-120	-11.88
-88500	-13700	-160	-15.84
-98000	-15200	-200	-19.80
-108500	-16850	-280	-27.72
-115000	-17850	-360	-35.69
-123000	-19100	-480	-47.52
-127000	-19700	-600	-59.40
-131000	-20300	-800	-79.20
-136000	-21100	-1000	-99.00

[illegible]

MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	16600	830
40	17900	447
60	18500	308
80	18900	236
100	19200	192

PERMEAMETER

$\mathcal{H}$	$\mathcal{B}$	μ
20	17000	850
40	19400	970
60	20500	340
80	21300	266
100	21800	218

80 60 40

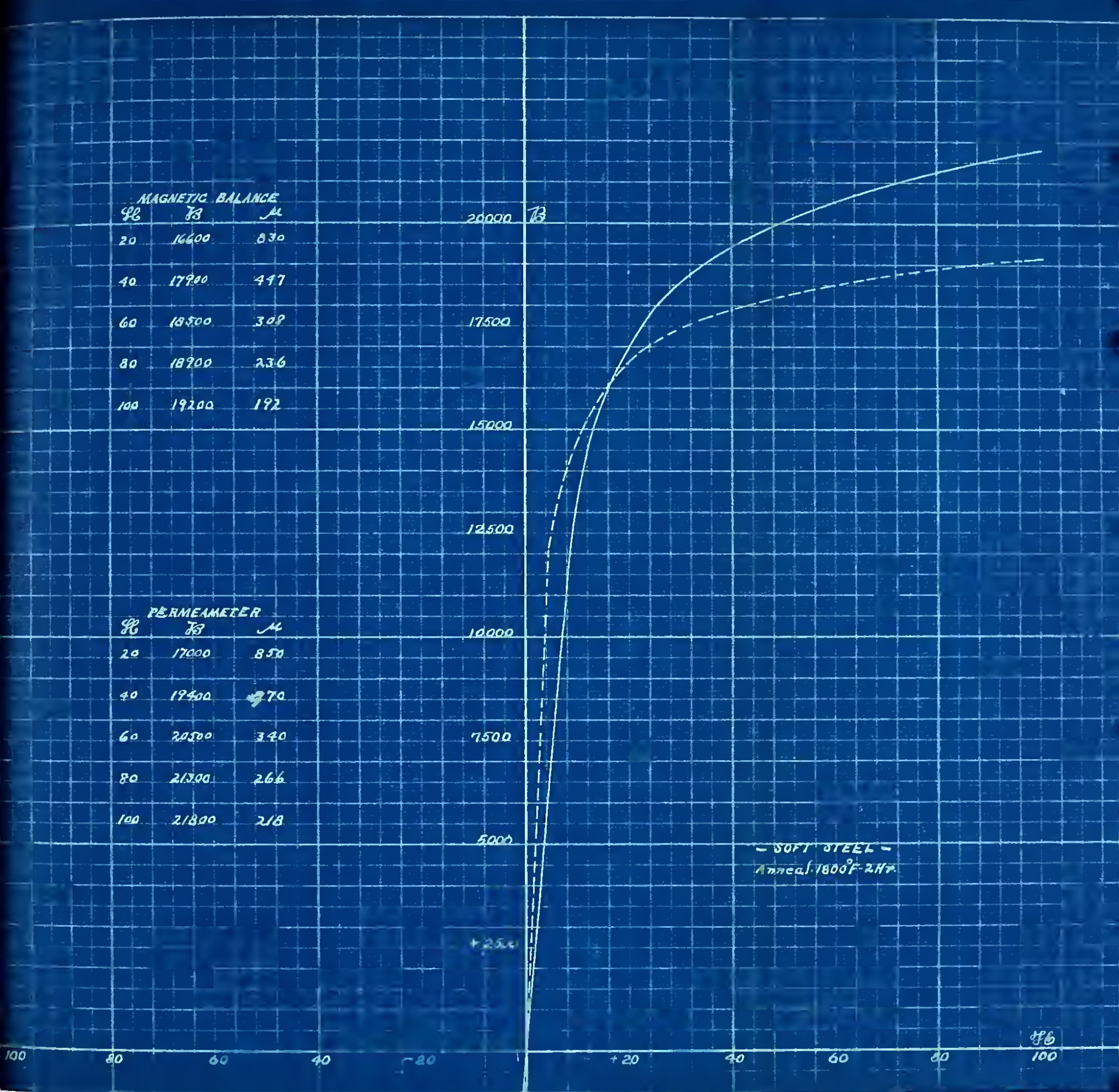
[illegible]

MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	16600	830
40	17900	447
60	18500	308
80	18900	236
100	19200	192

PERMEAMETER

$\mathcal{H}$	$\mathcal{B}$	μ
20	17000	850
40	19400	270
60	20500	340
80	21300	266
100	21800	218



Data for B-H Curve of Soft Steel (2) After Heating for Four Hours at 1800°F.

Obtained on Magnetic Balance

B	H	B	H
19100	99.80	0	-2.00
18450	58.20	-6000	-4.00
18000	39.90	-12150	-7.20
17100	20.00	-12300	-8.00
16250	10.00	-14450	-12.00
14700	6.00	-15650	-18.00
12650	2.10	-17150	-30.00
10400	0.0	-17750	-51.80
		-18350	-74.50
		-18950	-100.00

Data for B-H Curve of Soft Steel (B) After Heating for Four Hours at 1800°F.

Obtained on Esterline's Permeameter

b	B	h	H
131000	20300	1000	99.00
128000	19850	800	79.20
124000	19250	600	59.40
120000	18650	400	39.60
115000	17850	200	19.80
101000	15700	80	7.92
91000	14100	40	3.96
74000	11450	0	0.0
-34500	-6130	-80	-7.92
-100000	-15500	-200	-19.8
-114000	-17700	-400	-59.60
-121000	-18750	-600	-59.40
-125000	-19400	-800	-79.20
-129000	-20000	-1000	-99.00

MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	16400	820
40	17700	442
60	18400	307
80	18800	235
100	19000	190

PERMEAMETER

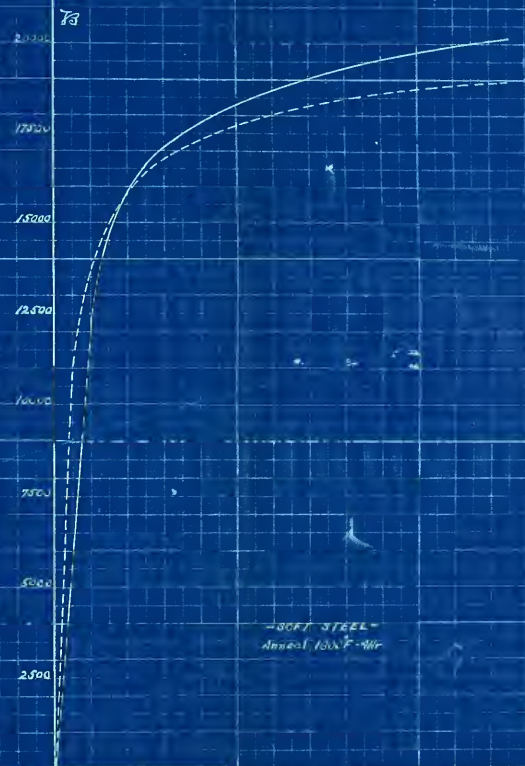
$\mathcal{H}$	$\mathcal{B}$	μ
20	16600	830
40	18300	460
60	19200	320
80	19800	248
100	20200	202

MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	16400	820
40	17700	442
60	18400	307
80	18800	235
100	17000	170

PERMEAMETER

$\mathcal{H}$	$\mathcal{B}$	μ
20	16600	830
40	18300	460
60	19200	320
80	19800	248
100	20200	202



Data for B-H Curve of Cast Steel (3) in Initial Condition.

Obtained on Magnetic Balance

B	H	B	H
16000	101.00	8000	-3.00
15650	80.00	5400	-6.00
15300	60.00	1300	-8.00
14500	40.00	-1100	-10.00
13800	30.00	-6000	-14.00
13400	26.00	-7300	-16.00
12650	20.00	-9000	-20.00
12300	16.00	-10750	-26.00
12050	14.00	-12000	-30.00
11600	10.00	-12500	-40.00
11100	8.00	-14300	-62.00
10630	6.00	-15150	-80.00
9850	3.00	-15900	-102.00
9400	0.0		

Data for B-H Curve of Cast Steel (3) in Initial Condition.

Obtained on Magnetic Balance

B	H	B	H
16000	101.00	8000	-3.00
15650	80.00	5400	-6.00
15300	60.00	1300	-8.00
14500	40.00	-1100	-10.00
13800	30.00	-6000	-14.00
13400	26.00	-7300	-16.00
12650	20.00	-9000	-20.00
12300	16.00	-10750	-26.00
12050	14.00	-12000	-30.00
11600	10.00	-12500	-40.00
11100	8.00	-14300	-62.00
10630	6.00	-15150	-80.00
9850	3.00	-15900	-102.00
9400	0.0		

Data for B-H Curve of Cast Steel (C) in Initial Condition.

Obtained on Esterline's Permeameter

b	B	h	H
99000	15350	1000	99.00
98500	15280	880	87.12
95000	14720	760	75.24
93000	14400	640	63.36
91500	14200	520	51.48
85500	13250	400	39.60
80000	12400	280	27.72
73000	11300	200	19.80
67000	10400	120	11.88
57500	8920	40	3.96
48500	7530	0	0.0
-1000	-155	-120	-11.88
-16500	-2560	-160	-15.84
-34000	-5270	-200	-19.60
-43500	-6750	-240	-23.76
-52000	-8060	-280	-27.72
-60000	-9300	-320	-31.68
-64500	-10000	-360	-35.64
-69000	-10700	-400	-39.60
-75000	-11600	-480	-47.52
-80000	-12400	-600	-59.40
-86500	-13400	-720	-71.28
-90500	-14050	-800	-79.20
-92000	-14250	-920	-91.08
-95000	-14720	-1000	-99.00

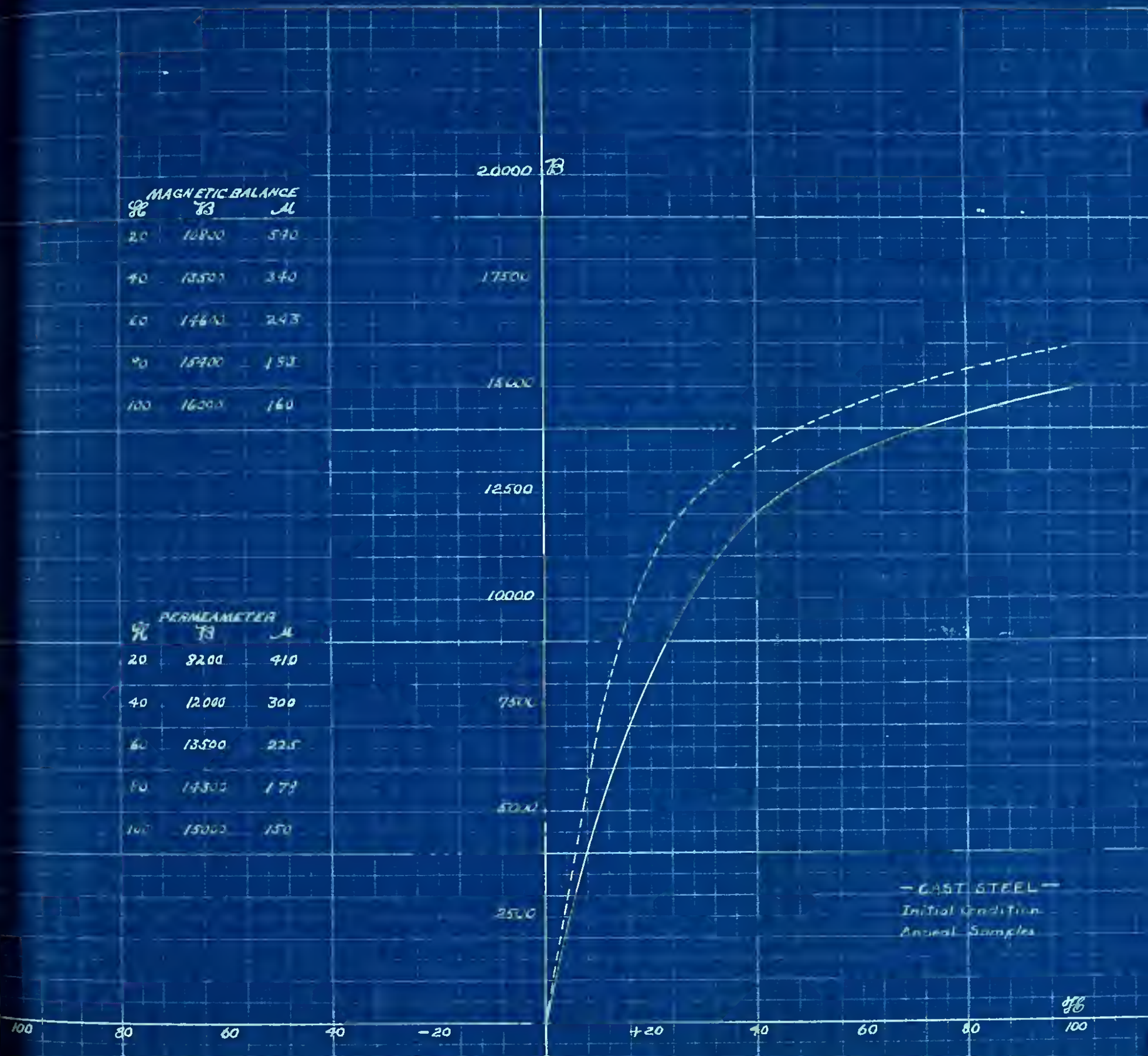
MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	10800	540
40	13500	340
60	14600	243
80	15700	183
100	16000	160

PERMEAMETER

$\mathcal{H}$	$\mathcal{B}$	μ
20	8200	410
40	12000	300
60	13500	225
80	14300	178
100	15000	150

80 60 40


MAGNETIC BALANCE
ℋ ℬ μ
20 12800 590
40 13500 340
60 14600 243
80 15400 193
100 16000 160
PERMEAMETER
ℋ ℬ μ
20 8200 410
40 12000 300
60 13500 225
80 14500 181
100 15000 150
20000 ℬ
17500
15000
12500
10000
7500
5000
2500
— CAST STEEL —
Initial Condition
Annealed Samples
ℋ
100 80 60 40 −20 +20 40 60 80 100

Data for B-H Curve of CastSteel (3) After Heating for Two Hours at 750°F.

Obtained on Magnetic Balance

B	H	B	H
16725	100.66	8500	-4.00
16300	78.00	7500	-5.00
15900	58.00	6200	-6.00
15500	40.00	2600	-6.66
13800	17.32	60	-8.00
13000	10.00	-1800	-10.00
12500	8.00	-3800	-12.00
11500	3.00	-8200	-16.00
10300	0.0	-10450	-20.00
		-13600	-30.66
		-14000	-40.20
		-15150	-60.40
		-16150	-80.66
		-16800	-104.00

Data for B-H Curve of Cast Steel (C) After Heating for Two Hours at 750°F.

Obtained on Esterline's Permeameter

b	B	h	H
105000	16300	1000	99.00
103000	16000	800	79.20
99500	15450	640	63.36
94500	14650	480	47.52
87000	13500	320	31.68
80000	12400	200	19.80
67500	10450	80	7.92
61000	9450	40	3.96
52400	8120	0	0.0
-19000	-2950	-160	-15.84
-37000	-5740	-200	-19.80
-49000	-7600	-240	-23.76
-57000	-8840	-280	-27.72
-74000	-11500	-400	-39.60
-90000	-13950	-600	-59.40
-98000	-15200	-800	-79.20
-105000	-16300	-1000	-99.00

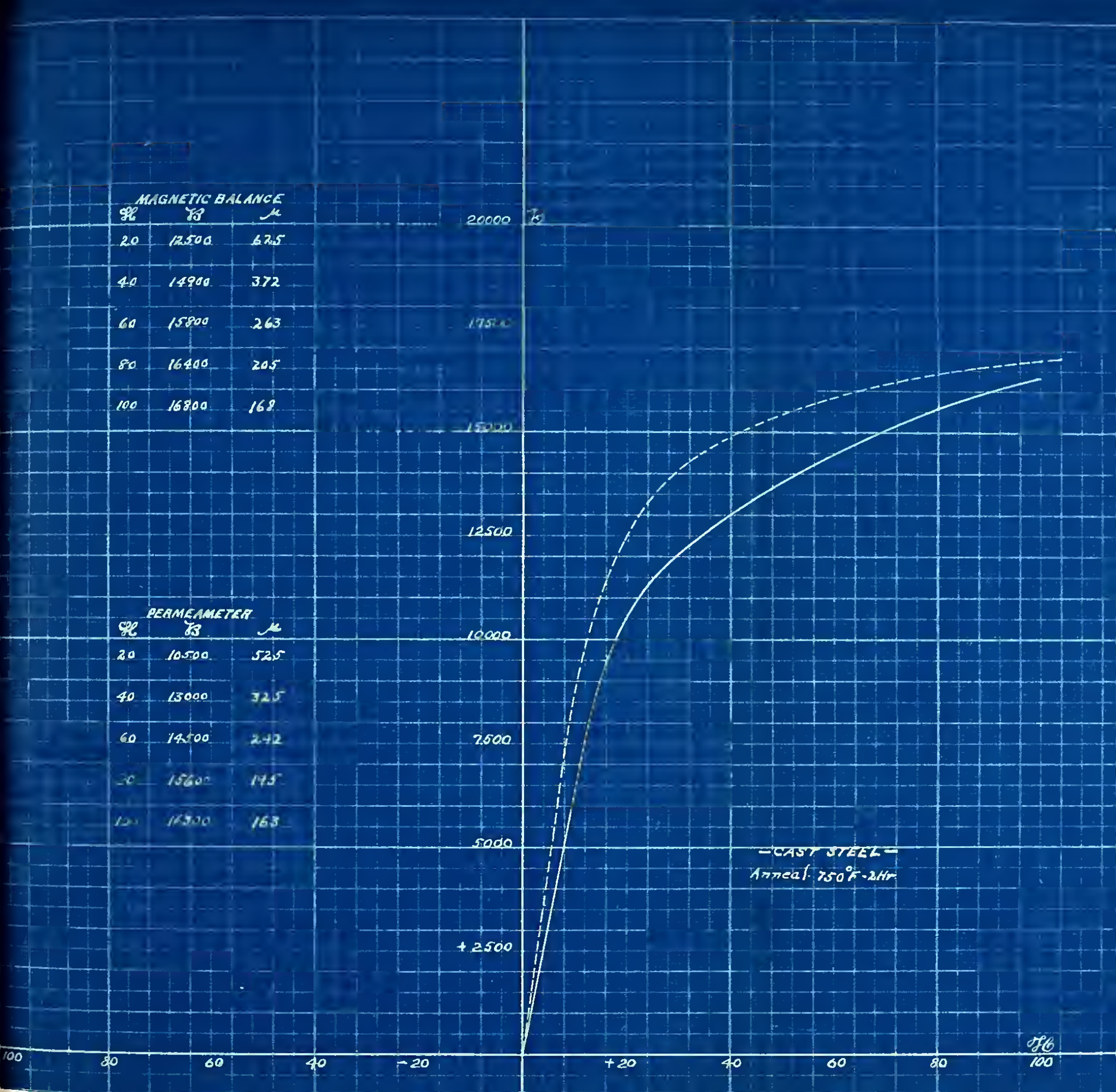
MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	12500	625
40	14900	372
60	15800	263
80	16400	205
100	16800	168

PERMEAMETER

$\mathcal{H}$	$\mathcal{B}$	μ
20	10500	525
40	13000	325
60	14500	242
80	15600	195
100	16300	163

80 60 40


MAGNETIC BALANCE
H B μ
20 12500 625
40 14900 372
60 15800 263
80 16400 205
100 16800 168
PERMEAMETER
H B μ
20 10500 525
40 13000 325
60 14500 242
80 15600 195
100 16300 163
20000 B
17500
15000
12500
10000
7500
5000
+2500
—CAST STEEL—
Anneal. 750°F-2Hr
H
100
80
60
40
-20
+20
40
60
80
100

Data for B-H Curve of Cast Steel (C) After Heating for Four Hours at 750°F.

Obtained on Esterline's Permeameter

b	B	h	H
99500	15430	1000	99.00
96000	14900	720	71.28
92000	14250	520	51.48
84000	13000	320	31.68
79000	12250	240	23.76
72500	11240	160	15.84
65500	10150	80	7.92
60000	9300	40	3.96
52000	8060	0	0.0
-46000	-7140	-240	-23.76
-62000	-9600	-320	-31.68
-83000	-12850	-520	-51.48
-93000	-14400	-720	-71.28
-98000	-15200	-880	-87.12
-100000	-15500	-1000	-99.00

MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20		
	NO DATA	
40		
60		
80		
100		

PERMEAMETER.

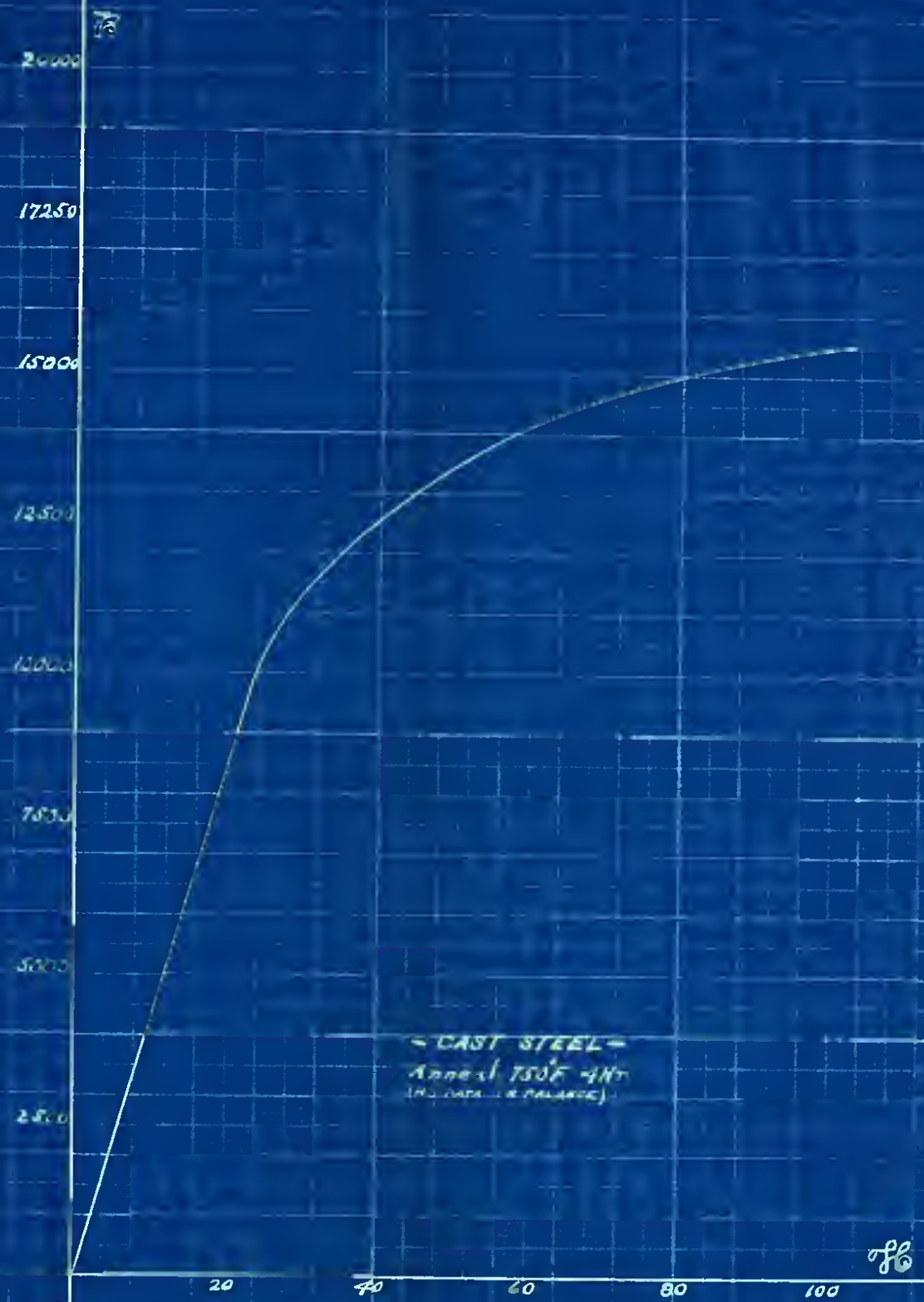
$\mathcal{H}$	$\mathcal{B}$	μ
20	8500	425
40	12500	312
60	14100	235
80	15000	187
100	15500	155

MAGNETIC BALANCE

H	B	μ
20	NO DATA	
40		
60		
80		
100		

PERMEAMETER.

H	B	μ
20	8500	425
40	12500	312
60	14100	235
80	15000	187
100	15500	155



Data for B-H Curve of Cast Steel (3) After Heating For Two Hours at 1000°F.

Obtained on Magnetic Balance

B	H	B	H
16750	100.66	9400	-2.00
16500	69.40	8600	-4.00
16000	39.32	7200	-5.00
14200	20.00	6400	-6.00
13900	18.00	1300	-8.00
13150	12.00	-1600	-10.00
12900	10.00	-3700	-12.00
11950	5.80	-6700	-14.00
10900	2.00	-8300	-16.00
10300	0.0	-10200	-20.00
		-13100	-30.00
		-14800	-51.00
		-15400	-70.80
		-16450	-102.66

Data for B-H Curve of Cast Steel (C) After Heating for Two Hours at 1000°F.

Obtained on Esterline's Permeameter

b	B	h	H
119000	18450	1000	99.00
116500	18050	800	79.20
113000	17540	600	59.40
105000	16300	400	39.60
93500	14500	200	19.80
80000	12400	80	7.92
72000	11150	40	3.96
62000	9600	0	0.0
-37500	-5820	-200	-19.80
-87000	-13500	-400	-39.60
-104000	-16150	-600	-59.40
-112000	-17400	-800	-79.20
-119000	-18500	-1000	-99.00

MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	12200	610
40	14800	370
60	15700	261
80	16300	204
100	16600	166

PERMEAMETER

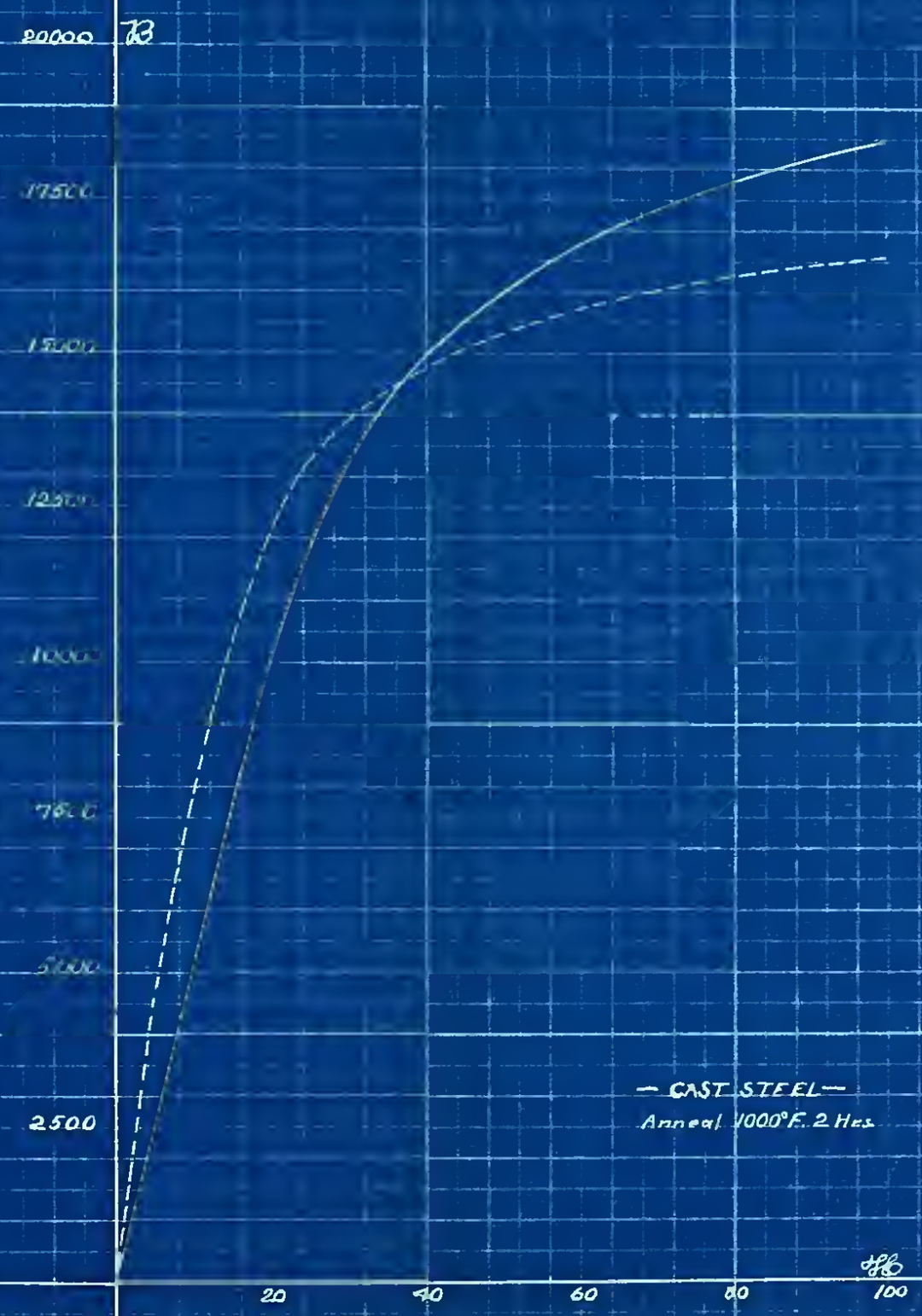
$\mathcal{H}$	$\mathcal{B}$	μ
20	10000	500
40	15000	375
60	16800	280
80	17800	222
100	19500	195

MAGNETIC BALANCE

$\mathcal{H}$	$\mathcal{B}$	μ
20	12200	610
40	14800	370
60	15700	261
80	16300	204
100	16600	166

PERMEAMETER

$\mathcal{H}$	$\mathcal{B}$	μ
20	10000	500
40	15000	375
60	16800	280
80	17800	222
100	18500	185



Data for B-H Curve of Cast Steel (3) After Heating for Four Hours at 1000°F.

Obtained on Magnetic Balance

B	H	B	H
16600	102.00	9700	-2.00
16200	69.40	9000	-3.80
15350	40.00	8000	-4.80
14150	20.00	5500	-6.00
12850	10.00	2500	-7.00
12050	6.00	1100	-8.00
11260	4.00	-1300	-10.00
10700	2.00	-3700	-12.00
10200	0.0	-7000	-14.00
		-9100	-18.00
		-11800	-24.20
		-13250	-38.20
		-14600	-50.20
		-15400	-71.00
		-16400	-102.00

Data for B-H Curve of Cast Steel (C) After Heating for Four Hours at 1000°F.

Obtained on Esterline's Permeameter

b	B	h	H
108500	16850	1000	99.00
106000	16450	800	79.20
104000	16140	600	59.40
100000	15500	400	39.60
90000	13950	240	23.76
80000	12400	160	15.84
65000	10050	80	7.92
58500	9070	40	3.96
50000	7750	0	0.0
1000	155	-120	-11.88
-10000	-1550	-160	-15.84
-32000	-4960	-200	-19.80
-39000	-6050	-240	-23.76
-50000	-7750	-280	-27.72
-60000	-9300	-320	-31.68
-71000	-11000	-400	-39.60
-82500	-12780	-480	-47.52
-90000	-13950	-600	-59.40
-98000	-15200	-720	-71.28
-105000	-16300	-880	-87.12
-107000	-16600	-1000	-99.00

MAGNETIC BALANCE

H	B	μ
20	12640	632.0
40	14250	356.3
60	15300	255.0
80	16050	200.6
100	16600	166.0

PERMEAMETER

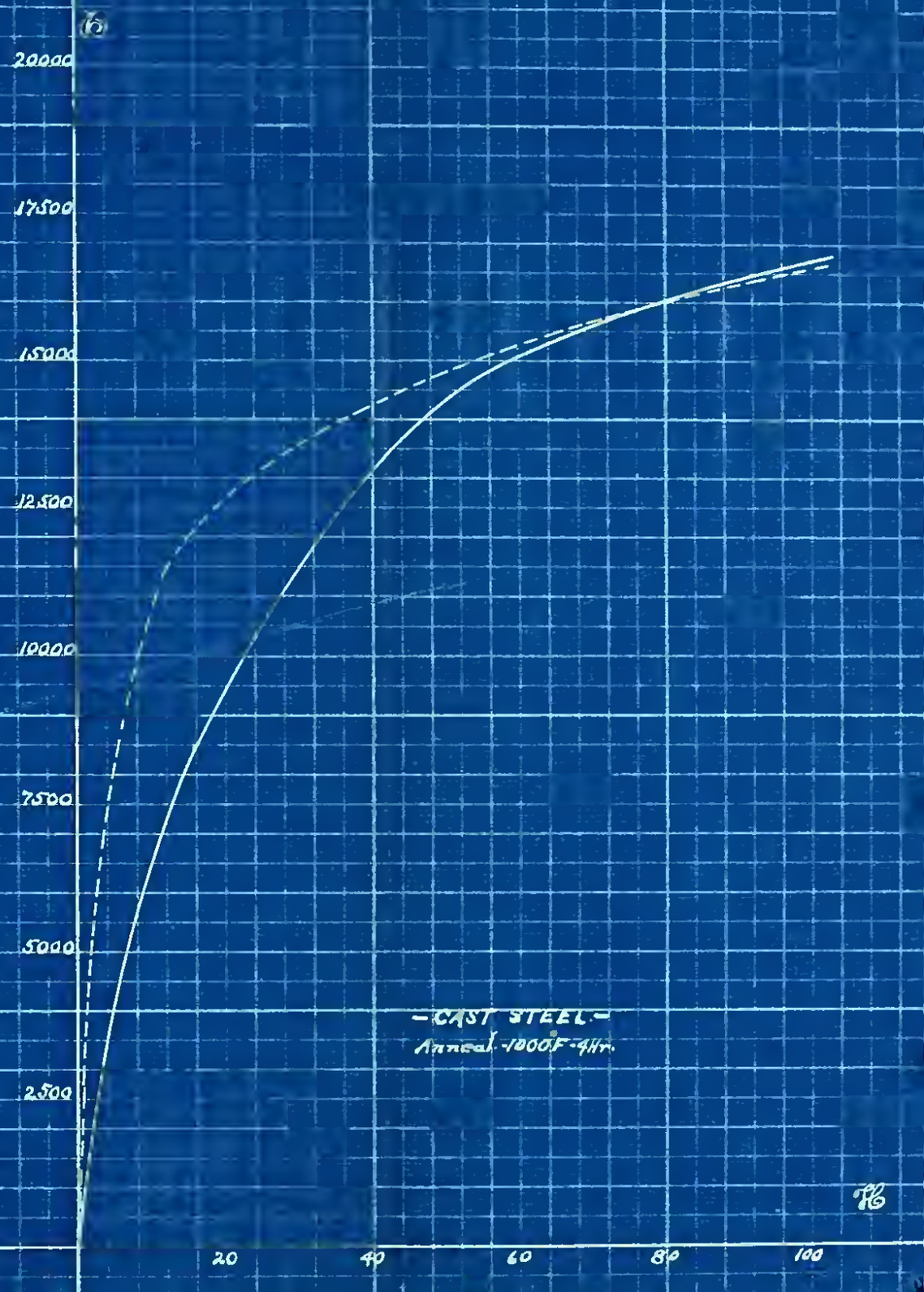
H	B	μ
20	9500	475.0
40	12650	316.3
60	15100	351.7
80	16050	200.6
100	16700	167.0

MAGNETIC BALANCE

H	B	μ
20	12640	632.0
40	14250	356.3
60	15300	255.0
80	16050	200.6
100	16600	166.0

PERMEAMETER

H	B	μ
20	9500	475.0
40	12650	316.3
60	15100	351.7
80	16050	200.6
100	16700	167.0



Data for B-H Curve Of Cast Steel (3) After Heating for Two Hours at 1800°F.

Obtained on Magnetic Balance

B	H	B	H
16700	100.00	-1300	-10.00
15850	55.00	-3500	-12.00
14350	30.00	-6000	-14.00
13550	20.00	-7850	-16.00
11900	10.00	-9000	-18.00
11400	5.80	-10150	-20.00
10250	2.00	-11700	-26.00
9450	0.0	-13100	-38.00
8150	- 2.00	-14100	-50.00
6350	- 4.00	-15500	-70.66
2800	- 6.00	-16600	-101.32
0	- 7.80		

Data for B-H Curve of Cast Steel (C) After Heating for Two Hours at 1800°F.

Obtained on Esterline's Permeameter

b	B	h	H
119000	18450	1000	99.00
117000	18150	800	79.20
112500	17450	600	59.40
105000	16300	400	39.60
92500	14340	200	19.80
82500	12800	120	11.88
78000	12090	80	7.92
63000	9760	0	00.00
-23000	-3570	-160	-15.84
-56000	-8690	-240	-23.76
-82000	-12700	-360	-35.64
-99000	-15350	-520	-51.48
-111000	-17200	-720	-71.28
-117000	-18150	-880	-87.12
-121000	-18750	-1000	-99.00

MAGNETIC BALANCE

H	B	μ
20	12000	600.0
40	14300	357.5
60	15400	256.7
80	16150	201.9
100	16700	167.0

PERMEAMETER

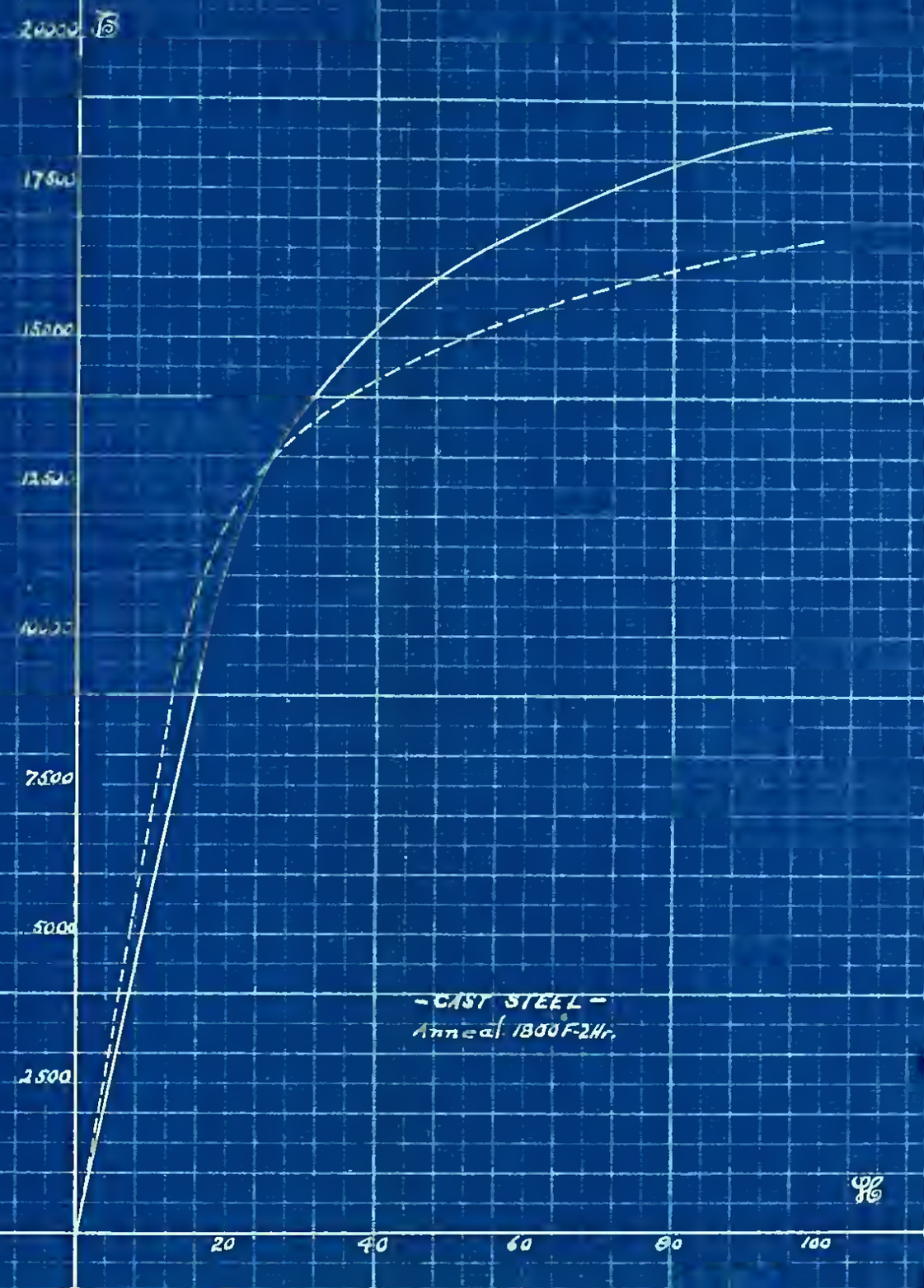
H	B	μ
20	11200	560.0
40	15200	380.0
60	16800	280.0
80	17900	223.8
100	18600	186.0

MAGNETIC BALANCE

H	B	μ
20	12000	600.0
40	14300	357.5
60	15400	256.7
80	16150	201.9
100	16700	167.0

PERMEAMETER

H	B	μ
20	11200	560.0
40	15200	380.0
60	16800	280.0
80	17900	223.8
100	18600	186.0



Data for B-H Curve of Cast STeel (3) After Heating for Four Hours at 1800°F.

Obtained on Magnetic Balance

B	H	B	H
17100	100.66	7000	-2.00
16620	67.6	3400	-4.00
15580	39.80	1400	-6.00
14200	20.00	0	-8.00
14050	14.00	-3300	-10.20
13550	10.20	-7500	-14.00
12400	6.00	-10700	-20.00
10500	0.0	-13000	-26.20
		-14000	-36.20
		-15100	-50.00
		-16000	-70.20
		-17000	-100.80

Data for B-H Curve of Cast Steel (C) After Heating for Four Hours at 1800°F.

Obtained on Esterline's Permeameter

b	B	h	H
112000	17390	1000	99.00
106500	16530	800	79.20
103500	16050	600	59.40
95000	14740	400	39.60
88500	13710	280	27.72
79000	12250	160	15.84
69500	10760	80	7.92
62000	9510	40	3.96
57500	8920	0	0.0
-8000	-1240	-120	-11.88
-30500	-4730	-160	-15.84
-44000	-6825	-200	-19.80
-58500	-9070	-240	-23.76
-69000	-10700	-280	-27.72
-79500	-12320	-360	-35.64
-87500	-13550	-440	-43.56
-94500	-14650	-560	-55.44
-103000	-16000	-680	-67.32
-117000	-18150	-840	-83.16
-122000	-18900	-1000	-99.00

MAGNETIC BALANCE

H	B	μ
20	12600	630.0
40	14900	372.5
60	16000	266.7
80	16650	208.1
100	17100	171.0

PERMEAMETER

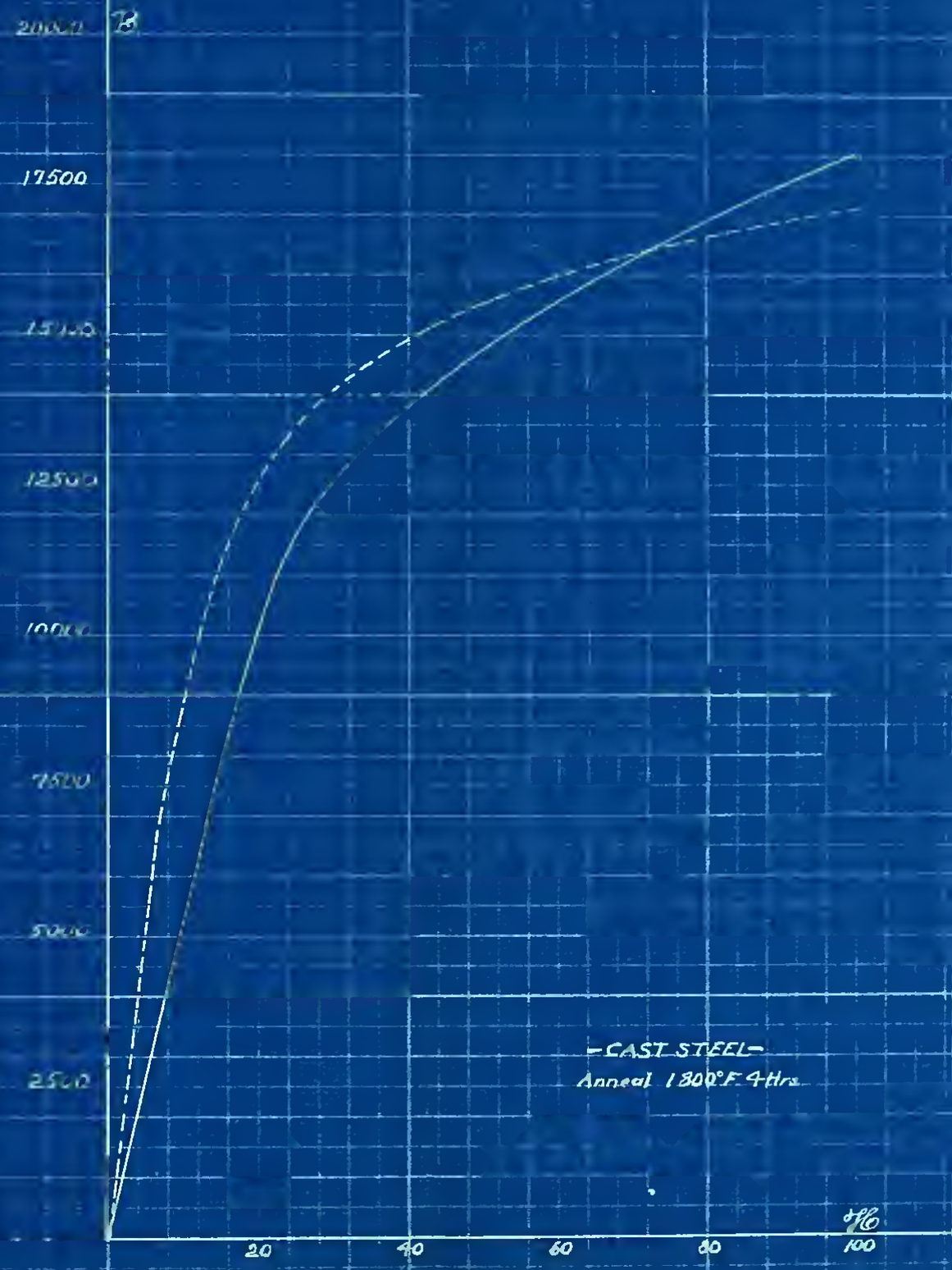
H	B	μ
20	10100	505.0
40	13800	345.0
60	15550	259.2
80	16400	205.0
100	18000	180.0

MAGNETIC BALANCE

H	B	μ
20	12600	630.0
40	14900	372.5
60	16000	266.7
80	[illegible]	205.1
100	17100	171.0

PERMEAMETER

H	B	μ
20	10100	505.0
40	13800	345.0
60	15550	259.2
80	16400	205.0
100	18000	180.0



Data for B-H Curve of Wrought Iron (4) in Initial Condition.

Obtained on Magnetic Balance

B	H	B	H
19300	100.66	3160	-2.20
19125	80.00	-9500	-4,20
18850	60.00	-11600	-6.66
18150	40.00	-12650	-9.00
17350	30.00	-12900	-10.00
17050	25.00	-14550	-13.80
16500	19.00	-15900	-20.00
15950	15.00	-17660	-30.00
14700	10.00	-18000	-40.00
14200	8.00	-18385	-50.00
13500	6.00	-18600	-60.00
11500	2.20	-19050	-81.00
9150	0.0	-19300	-100.60

[illegible]

Data for B- H Curve of Wrought Iron (D) in Initial Condition.

Obtained on Esterline's Permeameter

b	B	h	H
115000	17840	1000	99.00
112000	17390	880	87.12
111000	17210	760	75.24
109000	16900	640	63.36
107000	16600	520	51.48
103000	15970	400	39.60
96500	14950	280	27.72
89000	13800	200	19.80
72000	11150	120	11.88
55000	8540	40	3.96
37500	5820	0	0.0
-3000	-465	-40	-3.96
-56000	-8680	-120	-11.88
-76000	-11780	-200	-19.60
-87000	-13490	-280	-27.72
-98500	-15260	-400	-39.60
-103000	-15970	-520	-51.48
-106000	-16450	-640	-63.36
-109000	-16900	-760	-75.24
-111000	-17210	-1000	-99.00

MAGNETIC BALANCE

H	B	μ
20	16250	812.5
40	18050	451.3
60	18700	311.7
80	19100	238.8
100	19300	193.0

PERMEAMETER

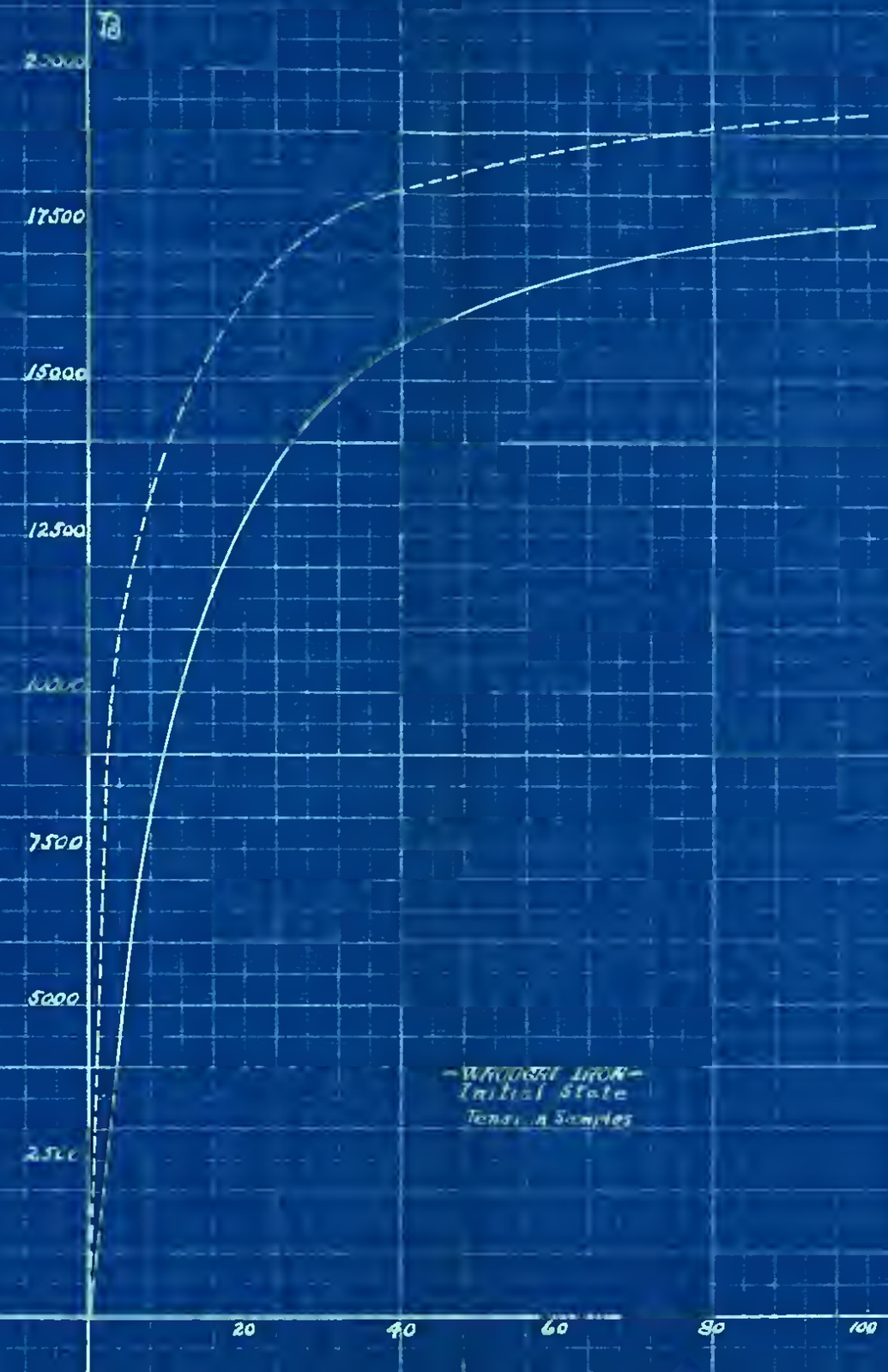
H	B	μ
20	12800	640.0
40	15600	390.0
60	16650	277.5
80	17200	215.0
100	17550	175.5

MAGNETIC BALANCE

H	B	μ
20	16250	812.5
40	17005	451.3
60	18700	311.7
80	19100	237.[illegible]
100	19800	198.0

PERMEAMETER

H	B	μ
20	12[illegible]	6[illegible]
40	15600	390.0
60	16560	277.5
80	17200	215.0
100	17550	175.5



Data for B-H Curve of Wrought Iron (4) After Being Subjected to a Tension of 5000 Pounds/Sq, In.

Obtained on Magnetic Balance

B	H	B	H
19150	100.00	2300	-2.20
18900	79.80	-10400	-6.00
18600	60.20	-11800	-8.00
18200	40.00	-13500	-10.00
17500	30.00	-14500	-14.00
16650	22.00	-15700	-20.00
16300	16.00	-17100	-30.00
14900	10.00	-17500	-40.00
14500	8.20	-18400	-60.40
13050	4.20	-18800	-80.80
12000	2.20	-19250	-100.00
9450	0.0		

Data for B-H Curve of Wrought Iron (D) After Being Subjected to a Tension of 5000 lbs./sq.in.

Obtained on Esterline's Permeameter

b	B	h	H
125000	19400	1000	99.00
121000	18760	800	79.20
119000	18450	640	63.36
117000	18150	480	47.52
109000	16900	320	31.68
100000	15500	200	19.80
81500	12630	80	7.92
70000	10850	40	3.96
52000	8060	0	0.0
-36500	-5660	-80	-7.92
-62500	-9700	-120	-11.88
-74500	-11550	-160	-15.84
-84000	-13000	-200	-19.80
-91500	-14190	-240	-23.76
-97000	-15100	-280	-27.72
-108500	-16850	-400	-39.60
117500	-18230	-600	-59.40
119500	-18550	-800	-79.20
124000	-19220	-1000	-99.00

MAGNETIC BALANCE

H	B	μ
20	16150	507.5
40	17750	443.8
60	18550	309.2
80	19000	237.5
100	19250	192.5

PERMEAMETER

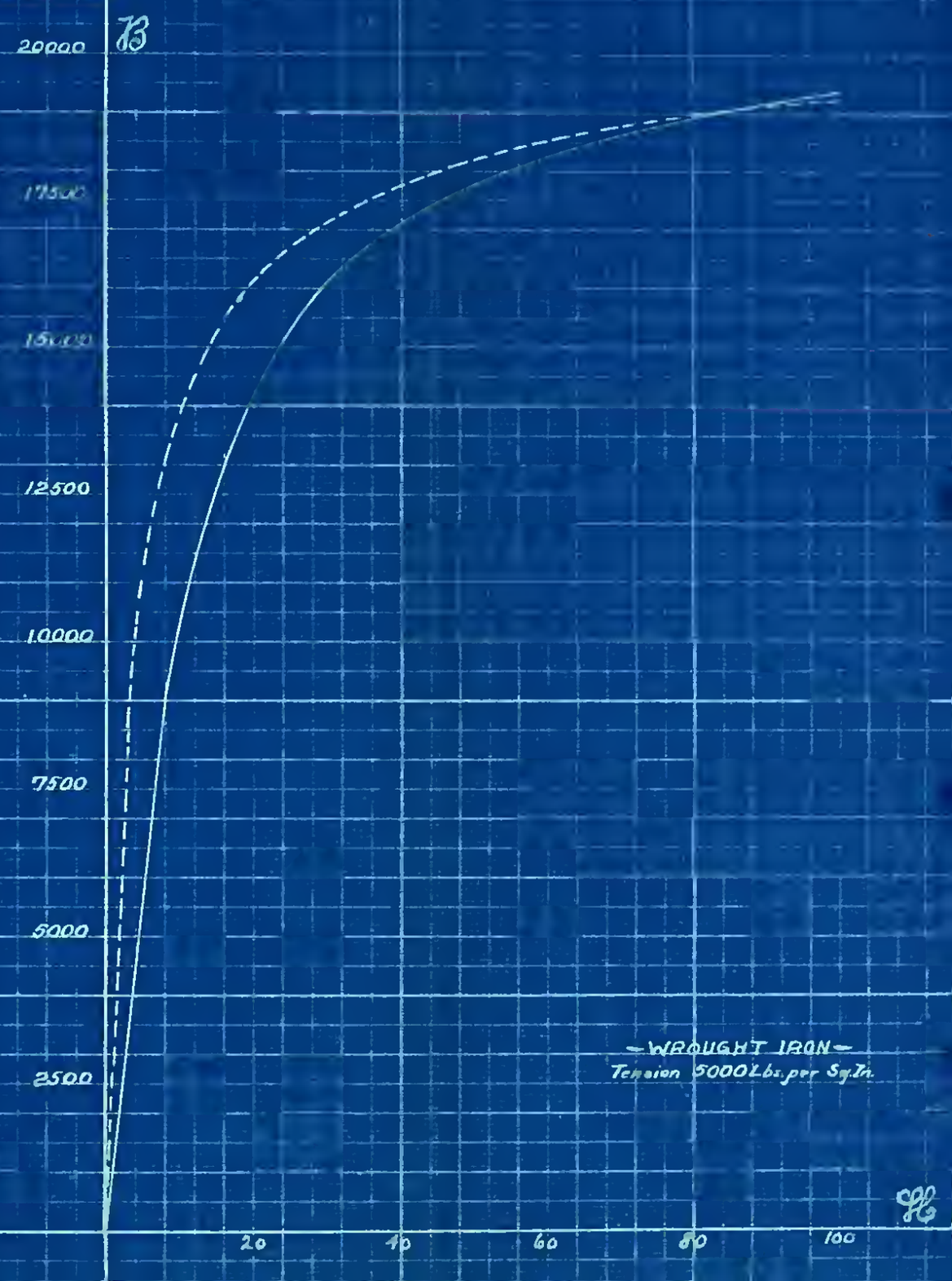
H	B	μ
20	14200	710.0
40	17150	428.8
60	18250	304.2
80	18900	237.5
100	19350	193.5

MAGNETIC BALANCE

H	B	μ
20	16150	807.5
40	17750	443.8
60	18550	309.2
80	19000	237.5
100	19250	192.5

PERMEAMETER

H	B	μ
20	14200	710.0
40	17150	428.8
60	18250	304.2
80	18900	237.5
100	19350	193.5



Data for B-H Curve of Wrought Iron (4) After Being Subjected to a tension of 10000 lbs./sq.in.

Obtained on Magnetic Balance

B	H	B	H
19750	99.60	-2800	-2.00
19375	79.00	-8700	-4.00
19000	60.00	-10750	-5.00
18400	40.00	-11150	-6.00
16600	18.00	-12250	-8.00
15500	12.00	-13800	-10.00
14850	10.00	-16300	-20.00
13700	6.00	-18150	-40.60
11600	2.00	-18900	-60.20
9300	0.0	-19200	-81.00
		-19650	-99.60

Data for B-H Curve of Wrought Iron (D) After Being Subjected to a Tension of 10000 lbs./sq.in.

Obtained on Esterline's Permeameter

b	B	h	H
120000	18600	1000	99.00
117000	18150	800	79.20
114500	17760	640	63.36
111000	17210	480	47.52
105000	16300	320	31.68
96000	14890	200	19.80
78000	12100	80	7.92
66000	10220	40	3.96
47000	7300	0	0.0
-2500	-388	-40	3.96
-38000	-5900	-80	-7.92
-82000	-12710	-200	-19.80
-98000	-15200	-320	-31.68
-107000	-16600	-480	-47.52
-112000	-17390	-640	-63.36
-115000	-17840	-800	-79.20
-119000	-18450	-1000	-99.00

MAGNETIC BALANCE

H	B	μ
20	16500	825.0
40	18250	456.3
60	19050	317.5
80	19450	243.1
100	19700	197.0

PERMEAMETER

H	B	μ
20	13700	685.0
40	16300	407.5
60	17400	290.0
80	18100	238.8
100	18600	186.0

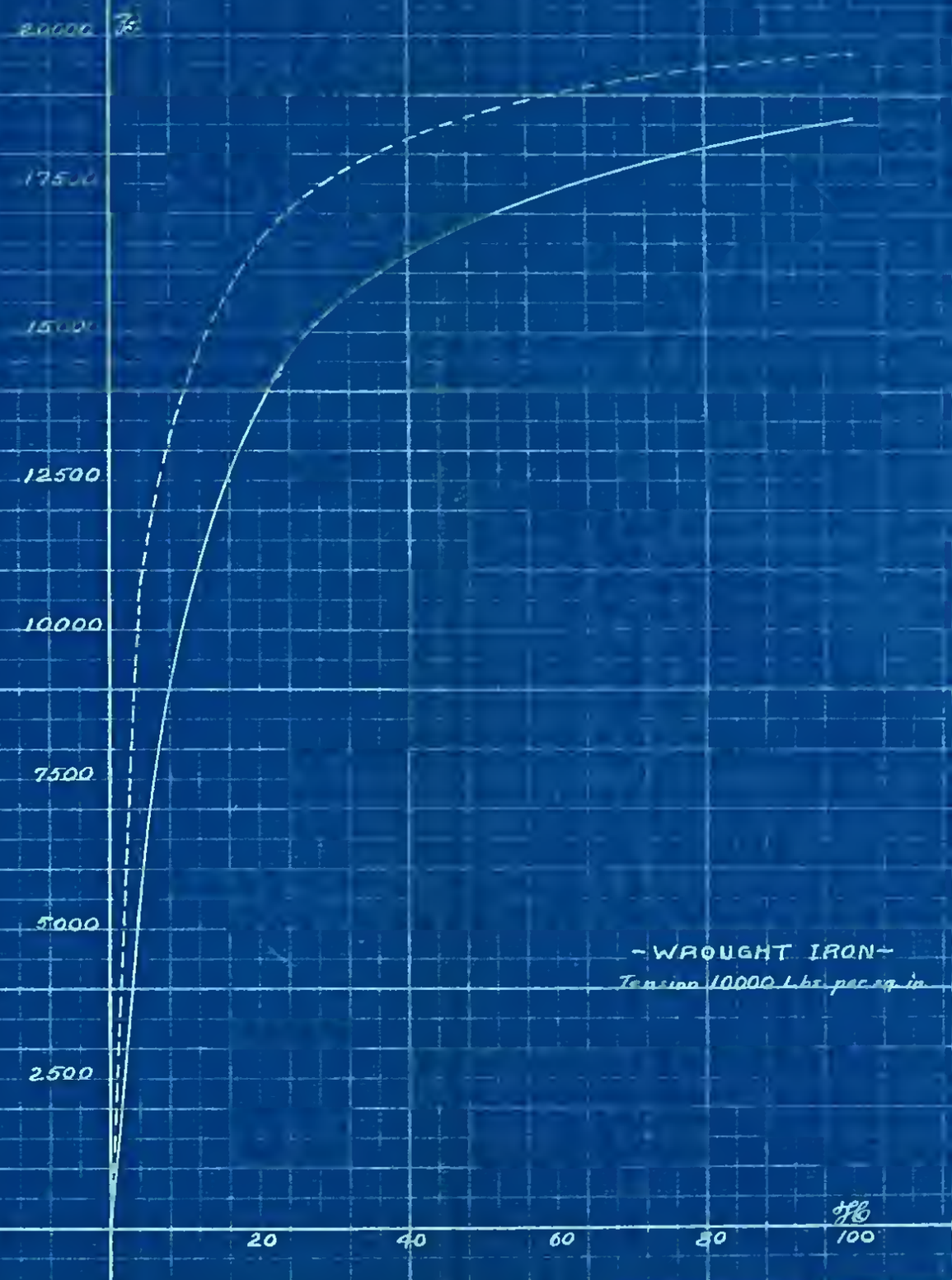
STANDARD CROSS SECTION MILLIMETER
KEUFFEL & ESSER CO., N. Y.

MAGNETIC BALANCE

H	B	μ
20	16500	825.0
40	18250	456.3
60	19050	317.5
80	19560	244.5
100	19700	197.0

PERMEAMETER

H	B	μ
20	13700	685.0
40	16300	407.5
60	17400	290.0
80	18100	238.8
100	18600	186.0



Data for B-H Curve of Wrought Iron (4) After Being Subjected to a Tension of 15000 lbs./sq.in.

Obtained on Magnetic Balance

B	H	B	H
19400	100.00	-9300	-4.00
19200	78.00	-13150	-10.00
18550	58.00	-14300	-14.00
18000	40.00	-15500	-20.00
17550	30.00	-17300	-36.00
16300	20.00	-17500	-40.00
16050	16.00	-18300	-61.00
15400	12.00	-19900	-84.00
14800	10.00	-19300	-102.00
14300	8.00		
13300	6.00		
11950	4.00		
9000	0.0		

Data for B-H Curve of Wrought Iron (D) After Being Subjected to a Tension of 15000 lbs./sq.in.

Obtained on Esterline's Permeameter

b	B	h	H
139000	21550	1000	99.00
136000	21100	800	79.20
131500	20400	600	59.40
126000	19540	400	39.60
120000	18600	280	27.72
114000	17690	200	19.80
103000	15970	120	11.88
95500	14800	80	7.92
80500	12470	40	3.96
59000	9150	0	0.0
-39000	-6050	-80	-7.92
-70500	-10920	-120	-11.88
-84500	-13100	-160	-15.84
-98000	-15200	-200	-19.80
-111000	-17210	-280	-27.72
-118500	-18400	-400	-39.60
-126000	-19550	-600	-59.40
-130500	-20260	-800	-79.20
-135000	-20950	-1000	-99.00

MAGNETIC BALANCE

H	B	μ
20	16200	810.0
40	17700	442.5
60	18400	306.7
80	18950	236.9
100	19300	193.0

PERMEAMETER

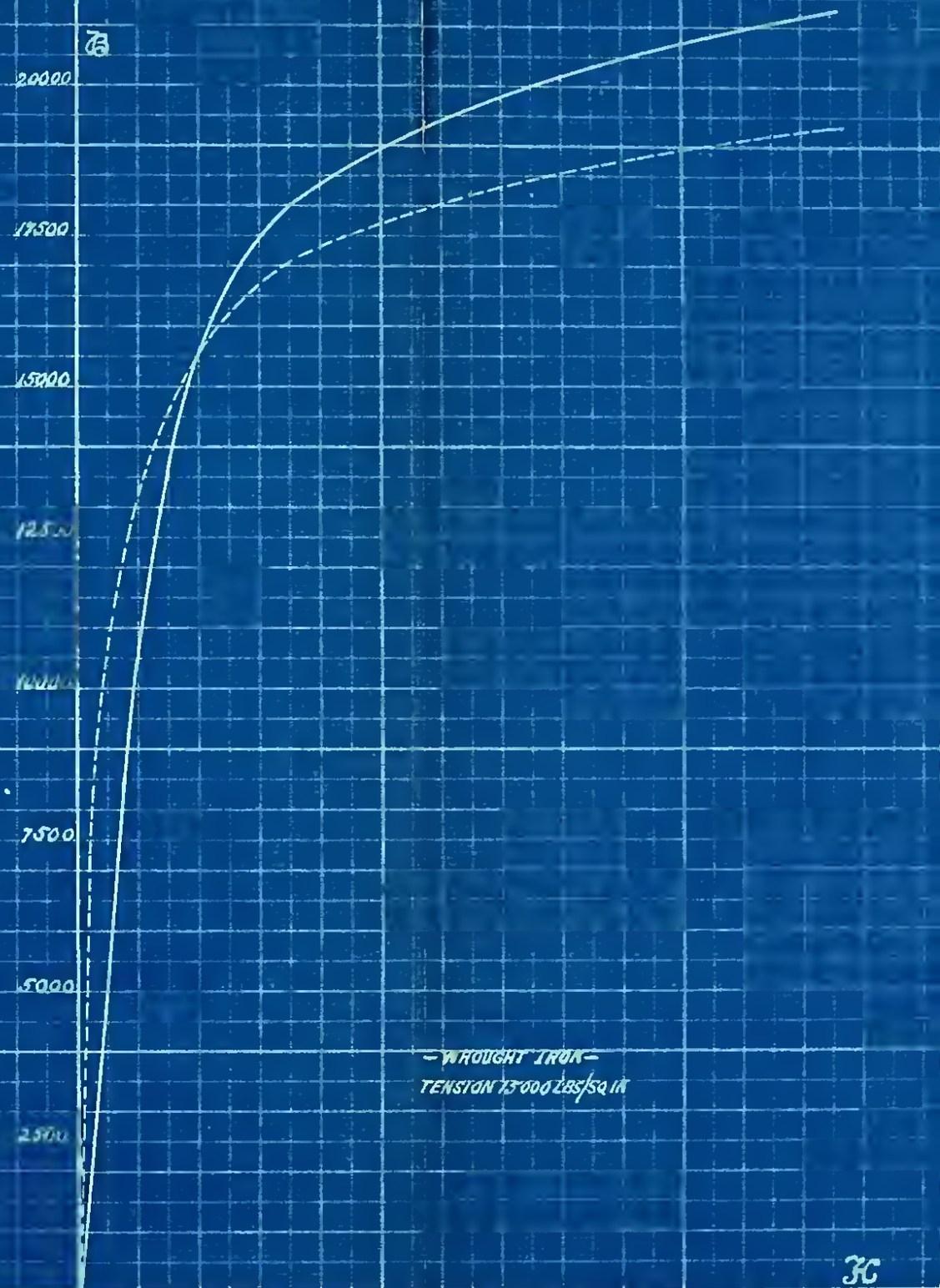
H	B	μ
20	16700	835.0
40	18950	473.8
60	20000	333.3
80	20750	259.4
100	21300	213.0

MAGNETIC BALANCE

H	B	μ
20	16200	810.0
40	17700	442.5
60	18400	306.7
80	18950	230.9
100	19300	193.0

PERMEAMETER

H	B	μ
20	16700	835.0
40	18250	456.1
60	20000	333.3
80	21750	272.4
100	21300	213.0



Data for B-H Curve of Wrought Iron (4) After Being Subjected to a Tension of 22000 lbs./sq.in.

Obtained on Magnetic Balance

B	H	B	H
19350	99.40	1300	-2.00
18950	69.20	-9600	-4.80
18400	40.00	-11000	-6.00
17200	20.00	-11750	-7.80
15200	10.00	-13250	-10.00
13400	6.00	-15450	-16.00
11600	2.80	-17500	-34.00
9000	0.0	-18100	-50.20
		-18520	-70.20
		-19200	-101.80

Data for B -H Curve of Wrought Iron (D) After Being Subjected to a Tension of 22000 lbs./sq.in.

Obtained on Esterline's Permeameter

b	B	h	H
128000	19850	1000	99.00
121000	18760	800	79.20
119000	18450	600	59.40
113000	17520	400	39.60
112000	17380	320	31.68
107000	16600	240	23.76
88000	13650	120	11.88
40000	6210	40	3.96
23000	3570	0	0.0
-6000	-930	-80	-7.92
-23000	-3570	-120	-11.88
-98000	-15200	-240	-23.76
-106000	-16450	-320	-31.68
-111000	-17210	-400	-39.60
-118000	-18300	-600	-59.40
-125000	-19390	-800	-79.20
-128000	-19850	-1000	-99.00

MAGNETIC BALANCE

H	B	μ
20	16450	822.5
40	18000	450.0
60	18700	311.7
80	19050	238.1
100	19250	192.5

PERMEAMETER

H	B	μ
20	14150	707.5
40	17350	433.8
60	18500	308.3
80	19300	241.3
100	19850	198.5

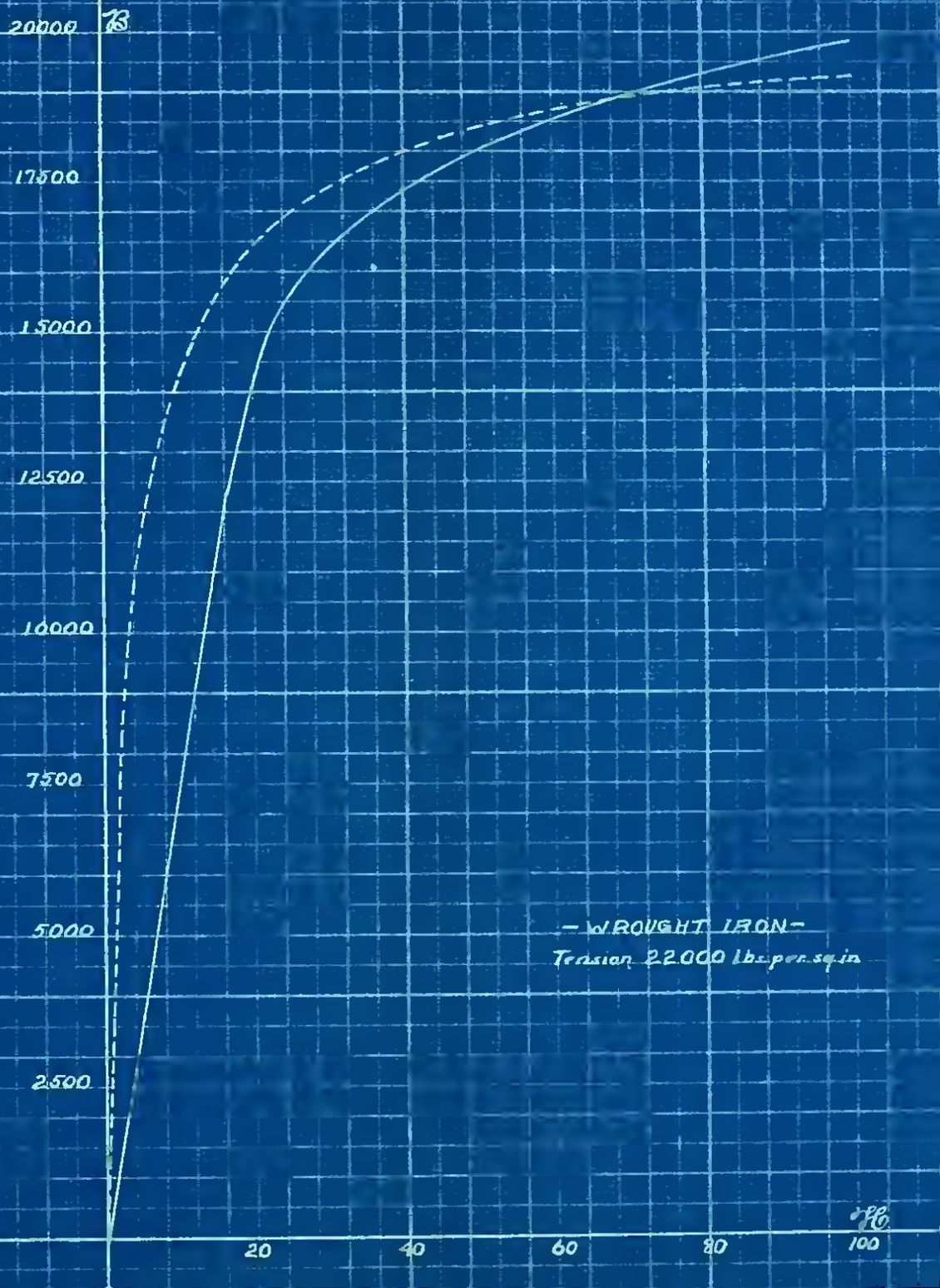
STANDARD CROSS SECTION MILLIMETER
KEUFFEL & ESSER CO., N. Y.

MAGNETIC BALANCE

H	B	μ
20	16450	822.5
40	18000	450.0
60	18700	311.7
80	19050	238.1
100	19250	192.5

PERMEAMETER

H	B	μ
20	14150	707.5
40	17350	433.8
60	18500	308.3
80	19300	241.3
100	19850	198.6



Data for B-H Curve of Soft Steel (5) in Initial Condition.

Obtained on Magnetic Balance

B	H	B	H
19400	101.00	9100	- 2.20
19150	79.00	0	- 4.20
18800	60.00	- 8200	- 6.80
18275	40.00	-10250	- 8.20
17900	20.00	- 11950	-10.00
17000	10.00	- 13600	-13.80
16800	8.00	- 15350	- 20.00
16275	6.00	-17350	-30.66
15400	4.50	- 18200	-50.00
14800	2.20	-18850	-71.00
13150	0.0	-19200	-90.66
		-19350	-101.00

[illegible]

Data for B-H Curve of Soft Steel (E) in Initial Condition.

Obtained on Esterline's Permeameter

b	B	h	H
112500	17460	1000	99.00
110000	17050	720	71.28
107000	16600	600	59.40
105000	16300	480	47.52
101000	15660	360	35.64
97000	15040	240	23.76
92500	14340	160	15.84
88500	13720	80	7.92
77500	12000	0	0.0
-24500	-3800	-80	-7.92
-69500	-10750	-120	-11.88
-86500	-13400	-160	-15.84
-91500	-14190	-200	-19.80
-95000	-14720	-240	-23.76
-100500	-15600	-360	-35.64
-106500	-16530	-480	-47.52
-109500	-17000	-600	-59.40
-114000	-17700	-760	-75.24
-114500	-17750	-880	-87.12
-117500	-18220	-1000	-99.00

MAGNETIC BALANCE

H	B	μ
20	16800	840.0
40	18100	452.5
60	18650	310.8
80	19050	238.1
100	19350	193.5

PERMEAMETER

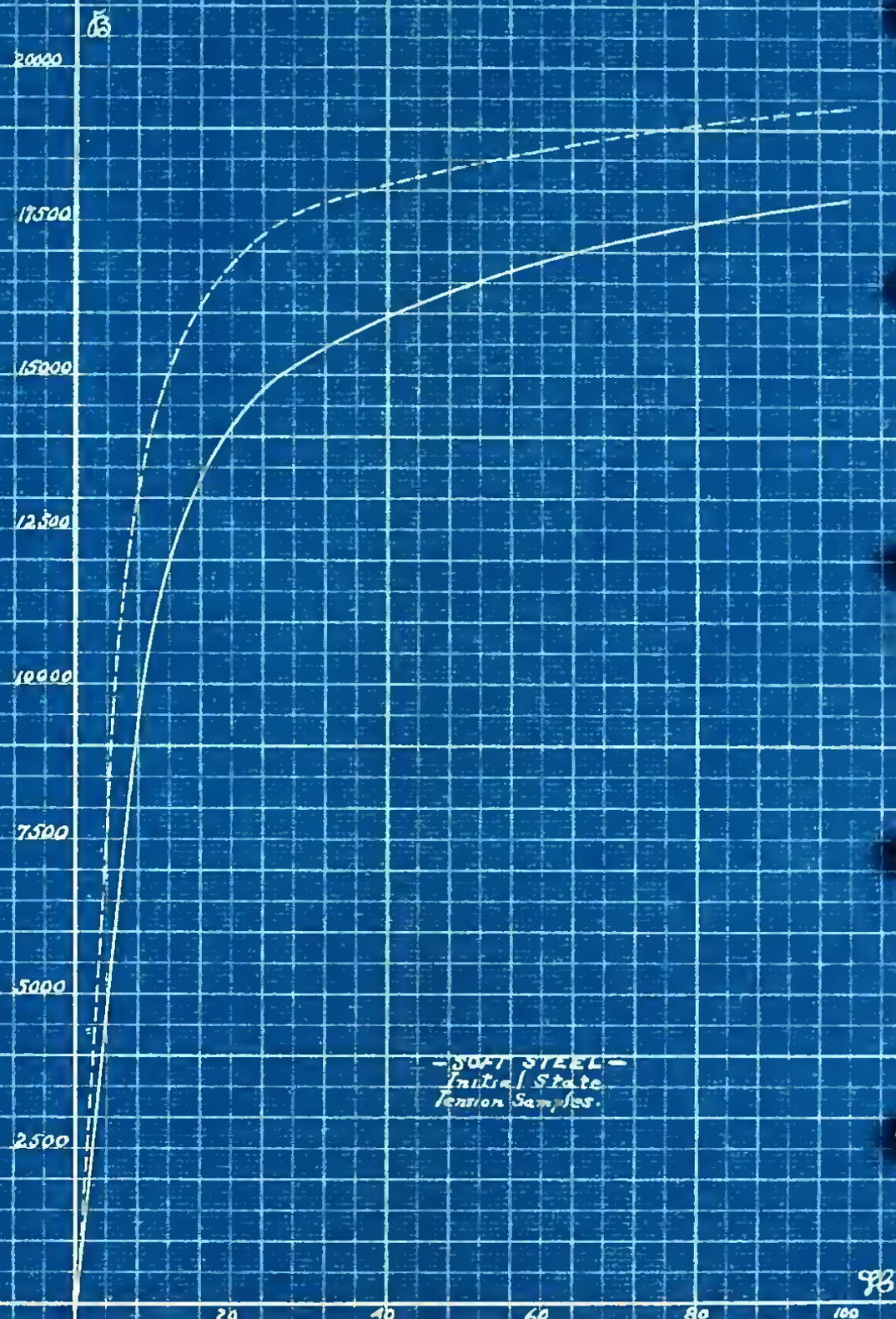
H	B	μ
20	14150	707.5
40	15950	398.8
60	16850	280.8
80	17450	218.1
100	17850	178.5

MAGNETIC BALANCE

H	B	μ
20	16800	840.0
40	18100	452.5
60	18650	310.8
80	19050	238.1
100	19350	193.5

PERMEAMETER

H	B	μ
20	14150	707.5
40	15950	398.8
60	16850	280.8
80	17450	218.1
100	17850	178.5



Data for B-H Curve of Soft Steel (5) After Being Subjected to a Tension of 5000 lbs./sq.in.

Obtained on Magnetic Balance

B	H	B	H
19050	100.00	6800	-2.20
18850	80.00	-3600	-4.50
18450	60.00	-8800	-6.00
18200	40.00	-11400	-8.00
17800	30.00	-13100	-10.00
17200	16.80	-14900	-14.00
16550	10.00	-16200	-20.00
16300	8.00	-17200	-30.00
14400	2.20	-17450	-40.20
12400	0.0	-18000	-60.00
		-18500	-81.00
		-18850	-100.00

Data for B-H Curve of Soft Steel (E) After Being Subjected to a Tension of 5000 lbs./sq.in.

Obtained on Esterline's Permeameter

b	B	h	H
124000	19230	1000	99.00
121000	18760	800	79.20
119000	18450	600	59.40
115000	17820	400	39.60
107000	16600	200	19.80
101000	15660	80	7.92
91000	14100	0	0.0
-22000	-3410	-80	-7.92
-80000	-12400	-120	-11.88
-90000	-13950	-160	-15.84
-97500	-15100	-200	-19.80
-104000	-16120	-280	-27.72
-111500	-17300	-400	-39.60
-118000	-18300	-600	-59.40
-121000	-18760	-800	-79.20
-124500	-19300	-1000	-99.00

MAGNETIC BALANCE

H	B	μ
20	16700	835.0
40	17850	446.3
60	18350	305.8
80	18850	235.6
100	19200	192.00

PERMEAMETER

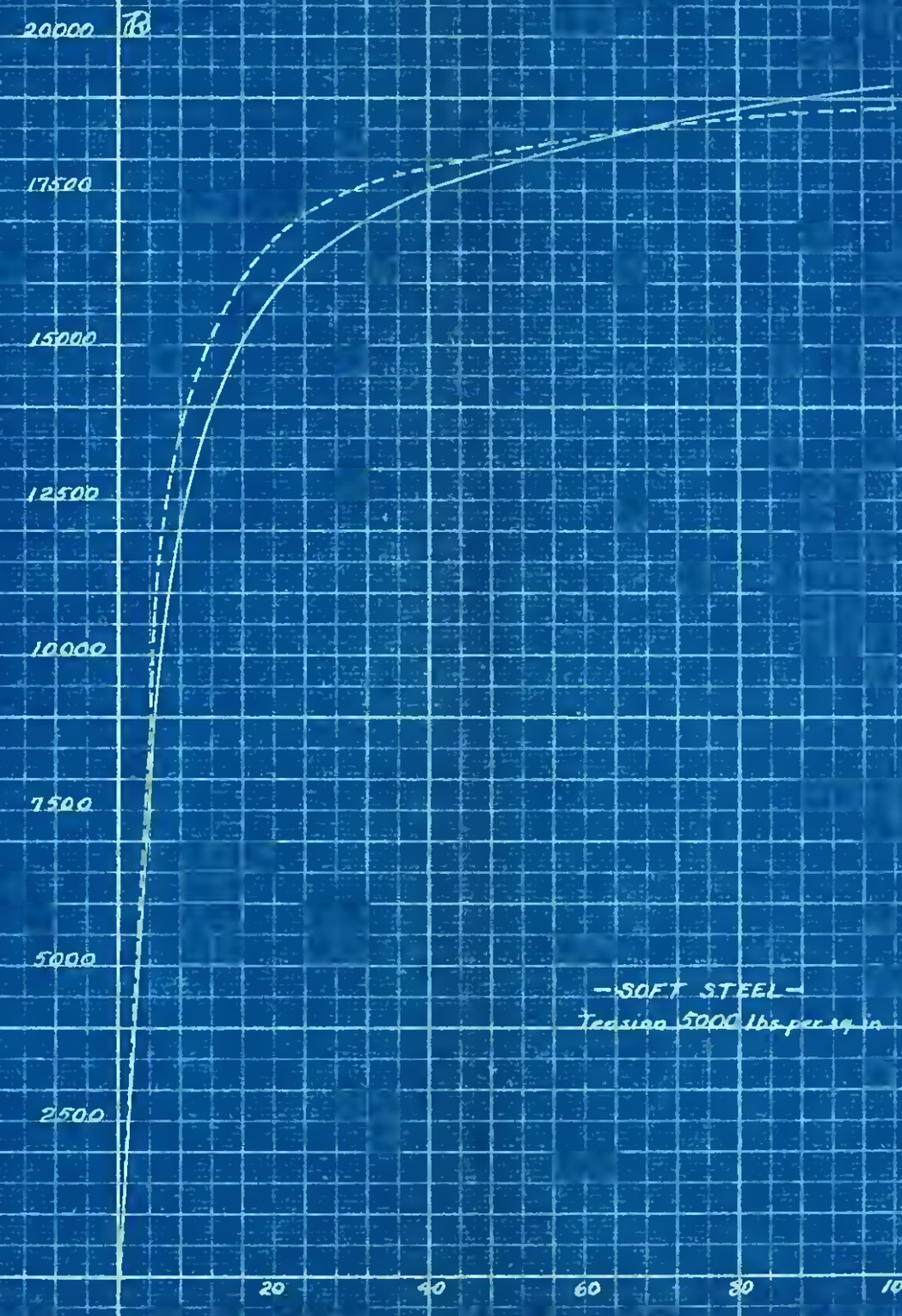
H	B	μ
20	15800	790.0
40	17500	437.5
60	18250	304.2
80	18850	260.6
100	20200	202.0

MAGNETIC BALANCE

H	B	μ
20	16700	835.0
40	17850	446.3
60	18350	305.8
80	18850	235.6
100	19200	192.00

PERMEAMETER

H	B	μ
20	15800	790.0
40	17500	437.5
60	18250	304.2
80	18850	260.6
100	20200	202.0



Data for B-H Curve of Soft Steel (5) After Being Subjected to a Tension of 15000 lbs/sq.in.

Obtained on Magnetic Balance

B	H	B	H
19050	100.60	7700	-2.00
18800	78.50	1200	-4.00
18650	59.60	-6300	-5.00
18350	40.00	-10750	-6.50
17300	17.00	-12650	-8.00
16750	10.00	-14200	-10.00
15900	6.00	-16000	-16.00
14450	2.20	-18000	-36.00
12750	0.0	-18250	-50.00
		-18850	-70.40
		-19250	-101.34

Data for B-H Curve of Soft Steel (E) After Being Subjected to a Tension of 15000 lbs./sq.in.

Obtained on Esterline's Permeameter

b	B	h	H
131500	20400	1000	99.00
130000	20150	800	79.20
122500	19000	600	59.40
119000	18450	440	43.56
113500	17600	280	27.72
107000	16600	160	15.84
103000	16000	80	7.92
92000	14250	0	0.0
-24000	-3725	-80	-7.92
-81000	-12550	-120	-11.88
-91000	-14100	-160	-15.84
-96500	-14960	-200	-19.80
-100000	-15200	-240	-23.76
-108500	-16830	-360	-35.64
-116000	-18000	-480	-47.52
-117500	-18210	-600	-59.40
-122000	-18900	-800	-79.20
-126000	-19550	-920	-91.08
-126000	-19550	-1000	-99.00

[illegible]

MAGNETIC BALANCE

H	B	μ
20	16590	847.5
40	18050	451.3
60	18600	310.0
80	18950	236.9
100	19100	191.0

PERMEAMETER

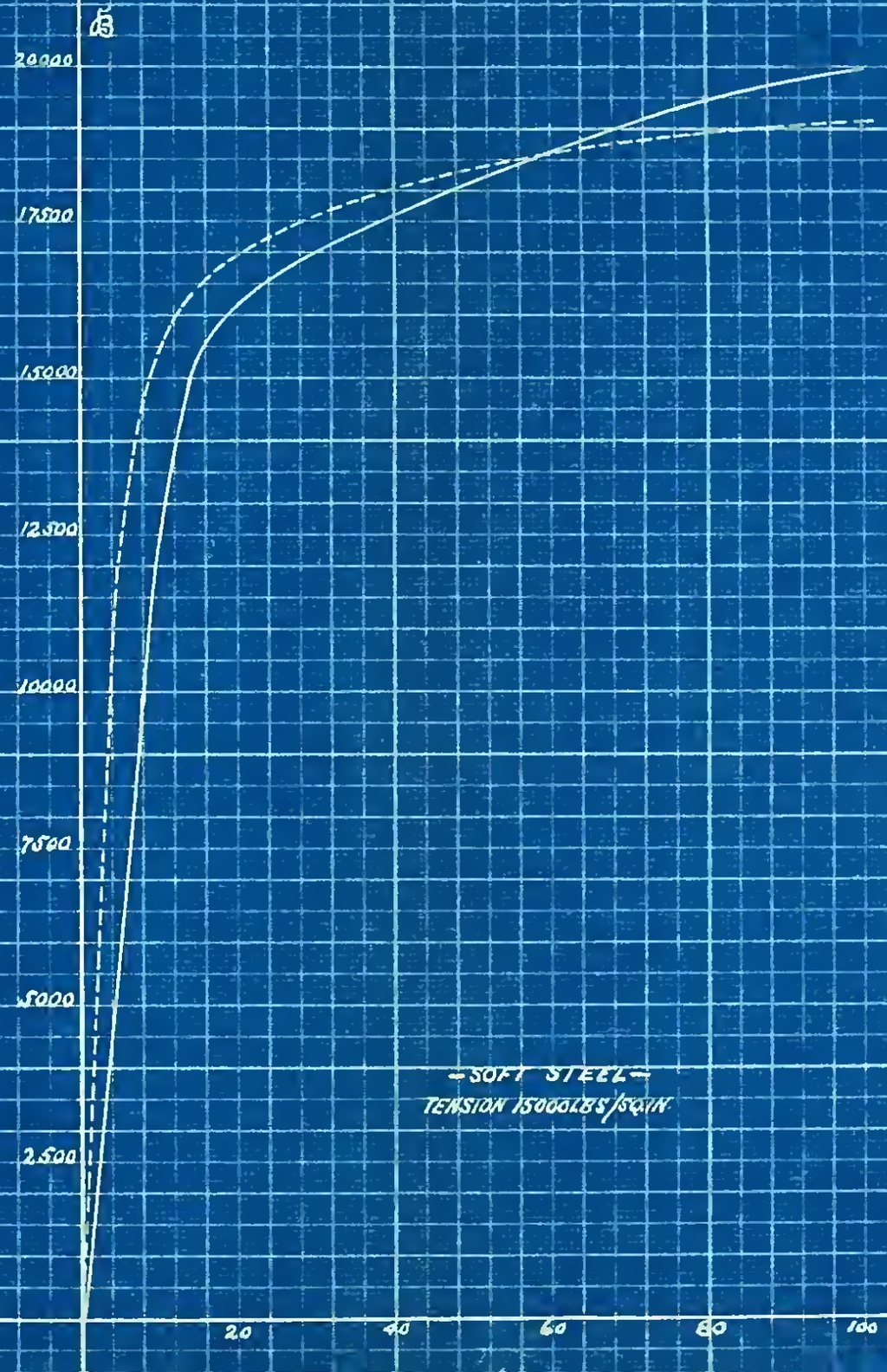
H	B	μ
20	16150	807.5
40	17600	440.0
60	18600	310.0
80	19450	243.1
100	19950	199.5

MAGNETIC BALANCE

H	B	μ
20	16590	847.5
40	18050	451.8
60	18600	310.0
80	18950	236.9
100	19100	191.0

PERMEAMETER

H	B	μ
20	16150	807.5
40	17600	440.0
60	18600	310.0
80	19450	243.1
100	19950	199.5



Data for B-H Curve of Soft Steel (5) After Being Subjected to a Tension of 25000 lbs/sq.in.

Obtained on Magnetic Balance

B	H	B	H
19100	100.00	7300	-5.00
18900	78.00	-11200	-8.00
18850	60.60	-13000	-10.00
18350	40.00	-15900	-20.00
18100	30.00	-17500	-36.00
17200	16.00	-17600	-40.00
16300	8.00	-18400	-60.00
15500	5.00	-18600	-83.00
12750	0.0	-19200	-100.00

Data for B-H Curve of Soft Steel (E) After Being Subjected to a Tension of 25000 lbs./sq.in.

Obtained on Esterline's Permeameter

b	B	h	H
136000	21100	1000	99.00
134000	20800	800	79.20
131000	20300	600	59.40
129000	20000	480	47.52
123500	19150	320	31.68
119000	18450	240	23.76
112000	17450	120	11.88
111000	17210	80	7.92
105000	16300	40	3.96
98000	15200	0	0.0
-36000	-5580	-80	-7.92
-85000	-13170	-120	-11.88
-112000	-17450	-240	-23.76
-119000	-18450	-320	-31.68
-125000	-19400	-480	-47.52
-130000	-20150	-600	-59.40
-135000	-20900	-800	-79.20
-139000	-21550	-1000	-99.00

MAGNETIC BALANCE

H	B	μ
20	16800	840.0
40	18000	450.0
60	18500	308.3
80	18900	236.3
100	19150	191.5

PERMEAMETER

H	B	μ
20	17200	860.0
40	19400	485.0
60	20250	337.5
80	20850	260.6
100	21300	213.0

MAGNETIC BALANCE

H	B	μ
20	16800	840.0
40	18000	450.0
60	18500	308.3
80	18900	236.3
100	19150	191.5

PERMEAMETER

H	B	μ
20	17200	860.0
40	19400	485.0
60	20250	337.5
80	20850	260.6
100	21300	213.0

Data for B-H Curve of Soft Steel (5) After Being Subjected to a Tension of 50000 lbs./sq.in.

Obtained on Magnetic Balance

B	H	B	H
18850	102.00	9000	-2.00
18350	68.00	0	-3.80
17800	40.00	-3600	-4.66
17200	20.00	-9000	-6.00
16200	10.00	-10500	-8.00
15350	6.00	-12000	-10.00
14350	2.00	-13000	-12.00
13000	0.0	-14450	-16.00
		-15900	-24.20
		-17250	-44.20
		-18000	-70.66
		-18600	-100.50

Data for B-H Curve of Soft Steel (E) After Being Subjected to a Tension of 50000 lbs./sq.in.

Obtained on Esterline's Permeameter

b	B	h	H
129000	20000	1000	99.00
126000	19550	800	79.20
121000	18750	600	59.40
117000	18150	400	39.60
112500	17450	320	31.68
103000	16000	240	23.76
100000	15500	160	15.84
93500	14500	80	7.92
83000	12850	0	0.0
-13000	-2015	-80	-7.92
-69000	-10700	-120	-11.88
-87000	-13490	-160	-15.84
-93000	-144100	-200	-19.80
-100000	-15500	-240	-23.76
-112000	-17450	-360	-35.64
-119000	-18450	-480	-47.52
-123500	-19150	-600	-59.40
-131000	-20300	-800	-79.20
-133500	-20700	-1000	-99.00

MAGNETIC BALANCE

H	B	μ
20	16000	800.0
40	17400	435.0
60	17850	297.5
80	18400	230.0
100	19750	197.5

PERMEAMETER

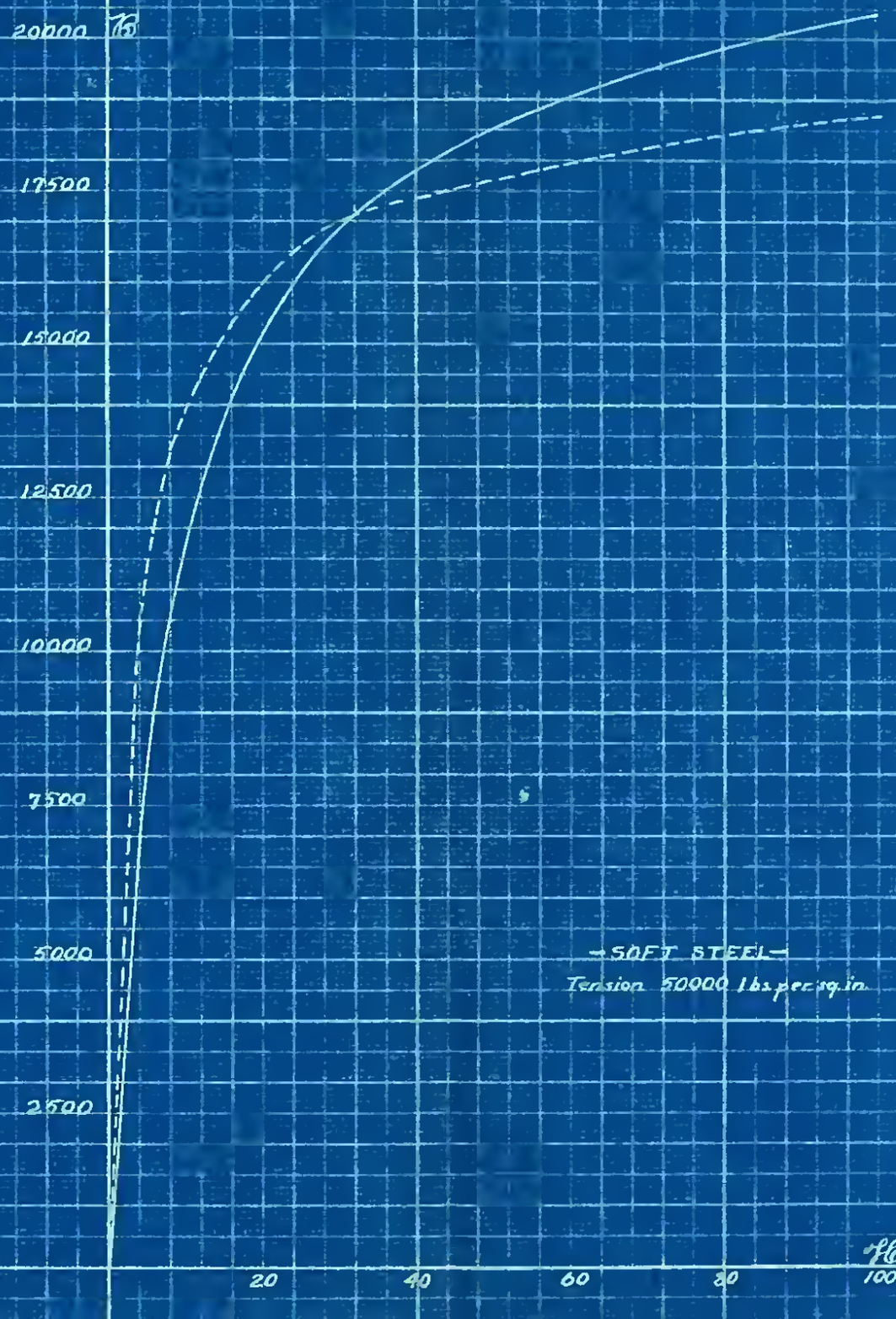
H	B	μ
20	15100	755.0
40	17800	445.0
60	19050	317.5
80	19800	247.5
100	20400	204.0

MAGNETIC BALANCE

H	B	μ
20	16000	800.0
40	17400	435.0
60	17850	297.5
80	18400	230.0
100	19750	197.5

PERMEAMETER

H	B	μ
20	15100	755.0
40	17800	446.0
60	19050	317.5
80	19800	247.5
100	20400	204.0



Data for B-H Curve of Cast Steel (6) in Initial Condition.

Obtained on Magnetic Balance

B	H	B	H
16620	101.00	10750	-2.20
16350	80.00	9500	-4.20
15900	60.00	9300	-6.00
15600	50.40	8700	-7.80
15170	40.00	6800	-10.00
14625	30.00	2560	-13.80
13500	16.66	0	-16.20
13400	14.00	0	-18.00
12400	10.00	-2100	-20.00
12200	7.80	-6000	-24.00
12050	6.00	-9800	-28.20
11800	2.20	-11200	-37.00
11300	0.0	-11800	-40.20
		-13450	-50.40
		-14400	-60.00
		-15200	-72.00
		-16050	-83.80
		-16450	-95.60
		-16500	-101.00

[illegible]

Data for B-H Curve of Cast Steel (F) in Initial Condition.

Obtained on Esterline's Permeameter

b	B	h	H
99000	15350	1000	99.00
96000	14870	720	71.28
92000	14250	600	59.40
90000	13950	480	47.52
84000	13000	360	35.64
77500	12000	240	23.76
71000	11000	160	15.84
63500	9850	80	7.92
52000	8070	0	0.0
-18000	-2790	-160	-15.84
-36000	-5580	-200	-19.80
-45000	--6980	-240	-23.76
-66000	-10220	-360	-35.64
-76000	-12780	-480	-47.52
-84500	-13100	-600	-59.40
-90000	-13950	-760	-75.24
-95000	-14710	-880	-87.12
-97000	-15030	-1000	-99.00

MAGNETIC BALANCE

H	B	μ
20	10350	517.5
40	13400	335.0
60	15100	251.7
80	16000	200.0
100	16500	165.0

PERMEAMETER

H	B	μ
20	8200	410.0
40	12250	306.3
60	13700	228.3
80	14600	182.5
100	15150	151.5

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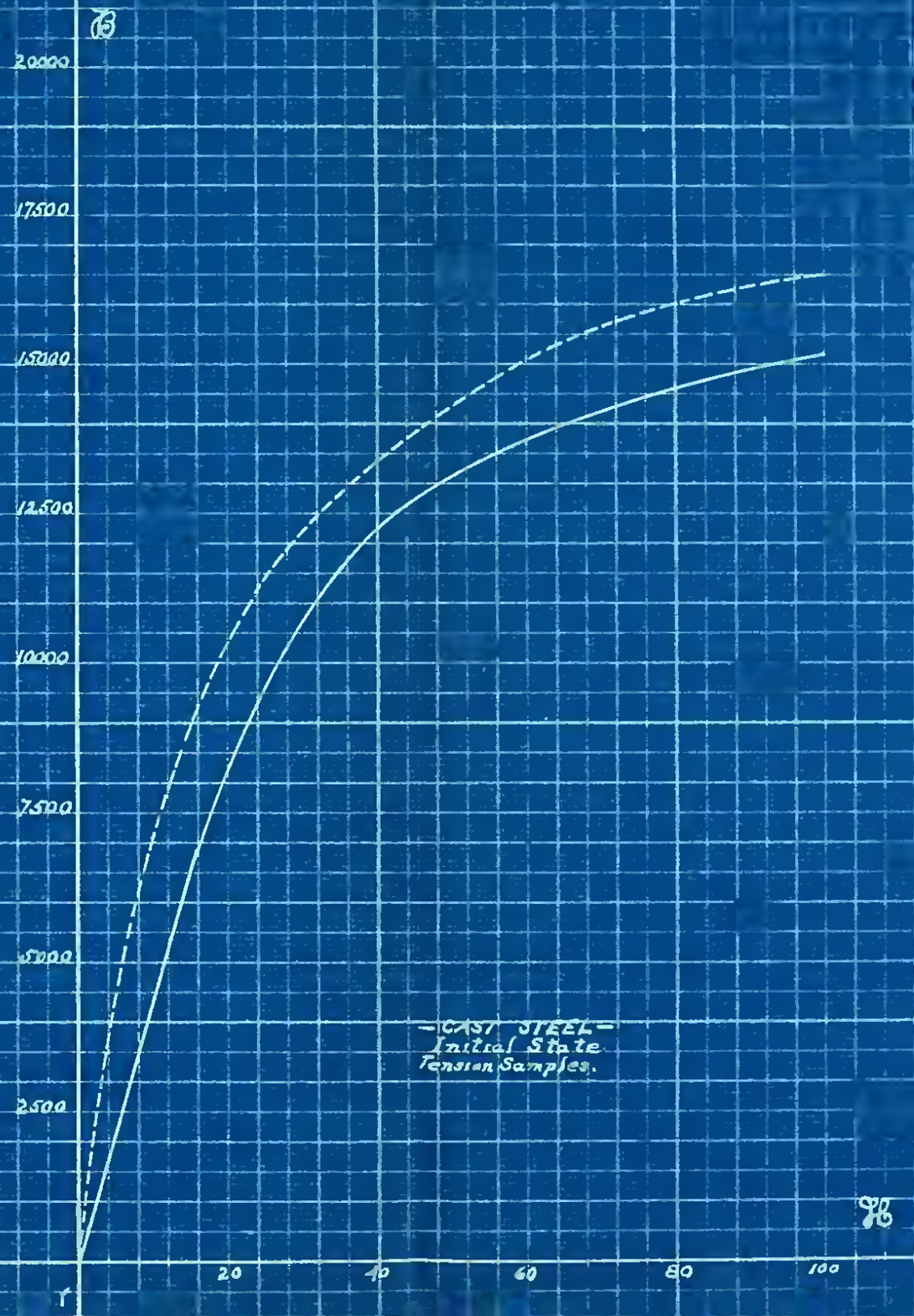
MAGNETIC BALANCE

H	B	μ
20	10350	517.5
40	13400	335.0
60	15100	251.7
80	16000	200.0
100	16500	165.0

PERMEAMETER

H	B	μ
20	8200	410.0
40	12250	306.3
60	13700	228.3
80	14600	182.5
100	15150	151.5



Data for B-H Curve of Cast Steel (6) After Being Subjected to a Tension of 11920 lbs./sq.in.

Obtained on Magnetic Balance

B	H	B	H
16650	100.00	10300	-2.20
16350	80.00	10000	-4.20
15700	60.00	9700	-6.00
15100	40.00	8600	-8.00
14500	30.00	7650	-10.00
14200	24.66	2400	-14.00
13400	17.20	0	-17.20
13000	14.00	-1500	-20.00
12600	10.00	-6000	-24.20
12200	8.00	-10800	-35.32
12000	6.00	-12400	-40.00
11400	2.20	-13700	-50.40
10750	0.0	-15000	-60.66
		-15600	-80.00
		-16250	-100.00

[illegible]

Data for B-H Curve of Cast Steel (F) After Being Subjected to a Tension of 11920 lbs./sq.in.

Obtained on Esterline's Permeameter

b	B	h	H
103500	16050	1000	99.00
102500	15900	800	79.20
98000	15200	600	59.40
92000	14250	400	39.60
88000	13640	280	27.72
79500	12320	160	15.84
71500	10080	80	7.92
66500	10300	40	3.96
59000	9150	0	0.0
-1000	-155	-120	-11.88
-20500	-3180	-160	-15.84
-39000	-6050	-200	-19.80
-53000	-8220	-240	-23.76
-62500	-9700	-280	-27.72
-69000	-10690	-320	-31.68
-89000	-13800	-480	-47.52
-90000	-13950	-600	-59.40
-98500	-15290	-800	-79.20
-103500	-16050	-1000	-99.00

MAGNETIC BALANCE

H	B	μ
20	8800	440.0
40	13750	343.8
60	15350	255.8
80	16000	200.0
100	16400	164.0

PERMEAMETER

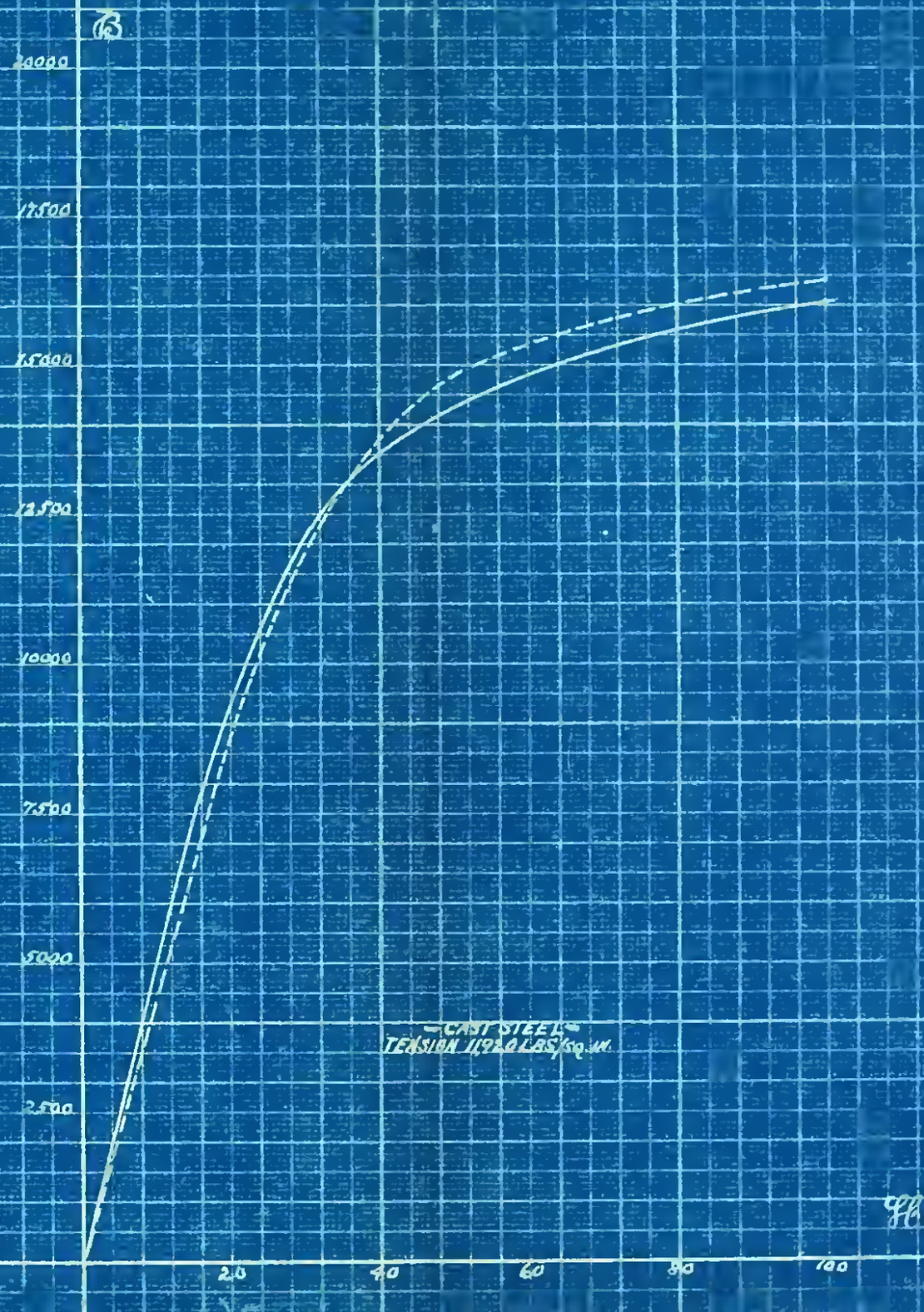
H	B	μ
20	9300	465.0
40	13500	337.5
60	14800	246.7
80	15600	195.0
100	16050	160.5

MAGNETIC BALANCE

H	B	μ
20	9800	490.0
40	13750	343.8
60	15350	255.8
80	16000	200.0
100	16400	164.0

PERMEAMETER

H	B	μ
20	9300	465.0
40	13500	337.5
60	14800	246.7
80	15600	196.0
100	16050	160.5



Data for B-H Curve of Cast Steel (6) After Being Subjected to a Tension of 30000 lbs./sq.in.

Obtained on Magnetic Balance

B	H	B	H
17200	100.00	10000	-2.00
16400	59.20	9600	-4.00
15050	30.00	9000	-6.00
13750	16.60	8100	-8.00
12850	10.00	6400	-10.00
12250	6.00	2800	-12.00
11500	2.00	0	-16.00
11200	0.0	-2800	-20.00
		-5400	-22.00
		-9600	-26.00
		-11800	-30.00
		-12650	-40.00
		-14550	-50.66
		-15700	-70.20
		-16600	-90.66
		-17100	-103.20

Data for B-H Curve of Cast Steel (F) After Being Subjected to a Tension of 30000 lbs./sq.in.

Obtained on Esterline'sPermeameter

b	B	h	H
102000	15810	1000	99.00
98500	15260	800	79.20
95000	14710	600	59.40
90750	14050	440	43.56
88000	13650	360	35.64
84330	13050	280	27.72
79000	12250	200	19.80
76500	11850	160	15.84
72500	11230	120	11.88
67500	10450	80	7.92
61500	9540	40	3.96
52670	8170	0	0.0
-3330	-516	-120	-11.88
-20500	-3180	-160	-15.84
-39000	-6050	-200	-19.80
-50000	-7750	-240	-23.76
-59500	-9720	-280	-27.72
-64000	-9920	-320	-31.68
-70000	-10840	-360	-35.64
-77500	-12000	-440	-43.56
-83000	-12850	-520	-51.48
-87000	-13500	-600	-59.40
-92500	-14340	-720	-71.28
-98500	-15260	-880	-87.12
-101500	-15750	-1000	-99.00

MAGNETIC BALANCE

H	B	μ
20	9500	475.0
40	14400	360.0
60	15750	262.5
80	16550	206.9
100	17100	171.0

PERMEAMETER

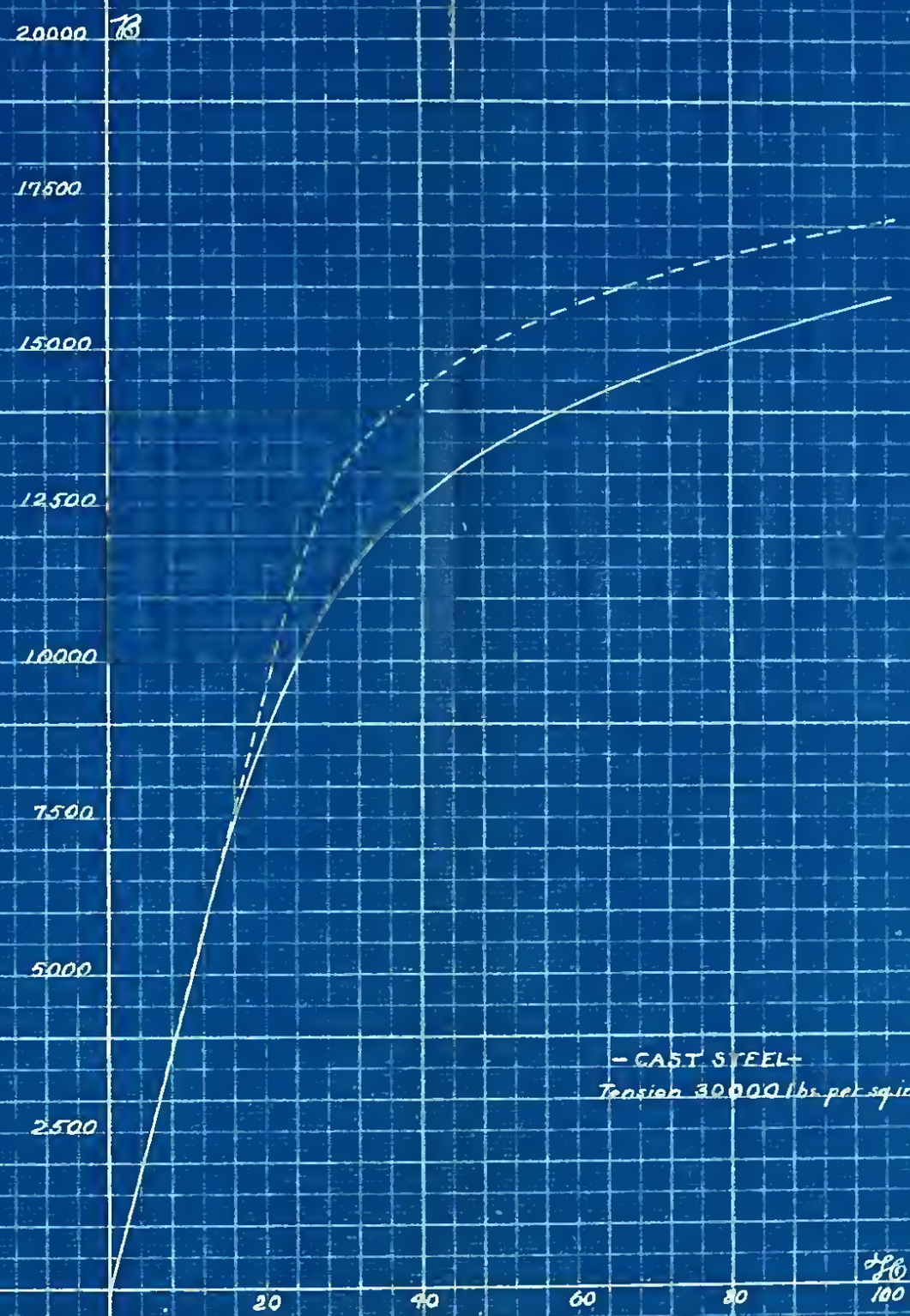
H	B	μ
20	8800	440.0
40	12600	315.0
60	14150	235.8
80	15100	188.8
100	15850	158.5

MAGNETIC BALANCE

H	B	μ
20	9500	475.0
40	14400	360.0
60	15750	262.5
80	16550	206.9
100	17100	171.0

PERMEAMETER

H	B	μ
20	8800	440.0
40	12600	315.0
60	14150	235.8
80	15100	188.8
100	15850	158.5



Data for B-H Curve of Cast Steel (6) After Being Subjected to a Tension of 50000 lbs./sq.in.

Obtained on Magnetic Balance

B	H	B	H
163500	101.00	9000	-4.00
15900	78.00	8500	-6.00
15600	61.00	6800	-10.00
14900	40.00	1100	-16.00
14100	30.00	600	-20.00
12900	18.50	-11450	-40.00
12000	10.00	-14250	-60.80
11850	8.00	-15600	-84.00
11300	6.00	-16200	-100.00
11000	4.00		
10000	0.0		

Data for B-H CURVE of Cast Steel (F) After Being Subjected to a Tension of 50000 lbs./sq.in.

Obtained on Esterline's Permeameter

b	B	h	H
111000	17210	1000	99.00
109000	16900	800	79.20
105000	16290	600	59.40
99000	15350	480	47.52
90500	14000	320	31.68
85000	13190	240	23.76
70000	10850	120	11.88
66000	10220	80	7.92
59500	9225	40	3.96
49000	7600	0	0
-9000	-1395	-160	-15.84
-30000	-4650	-200	-19.80
-36500	-5660	-240	-23.76
-58000	-9000	-320	-31.68
-82000	-12700	-480	-47.52
-93000	-14420	-600	-59.40
-102000	-15810	-800	-79.20
-108000	-16740	-1000	-99.00

MAGNETIC BALANCE

H	B	μ
20	9800	490.0
40	13000	325.0
60	14850	247.5
80	15700	196.3
100	16150	161.5

PERMEAMETER

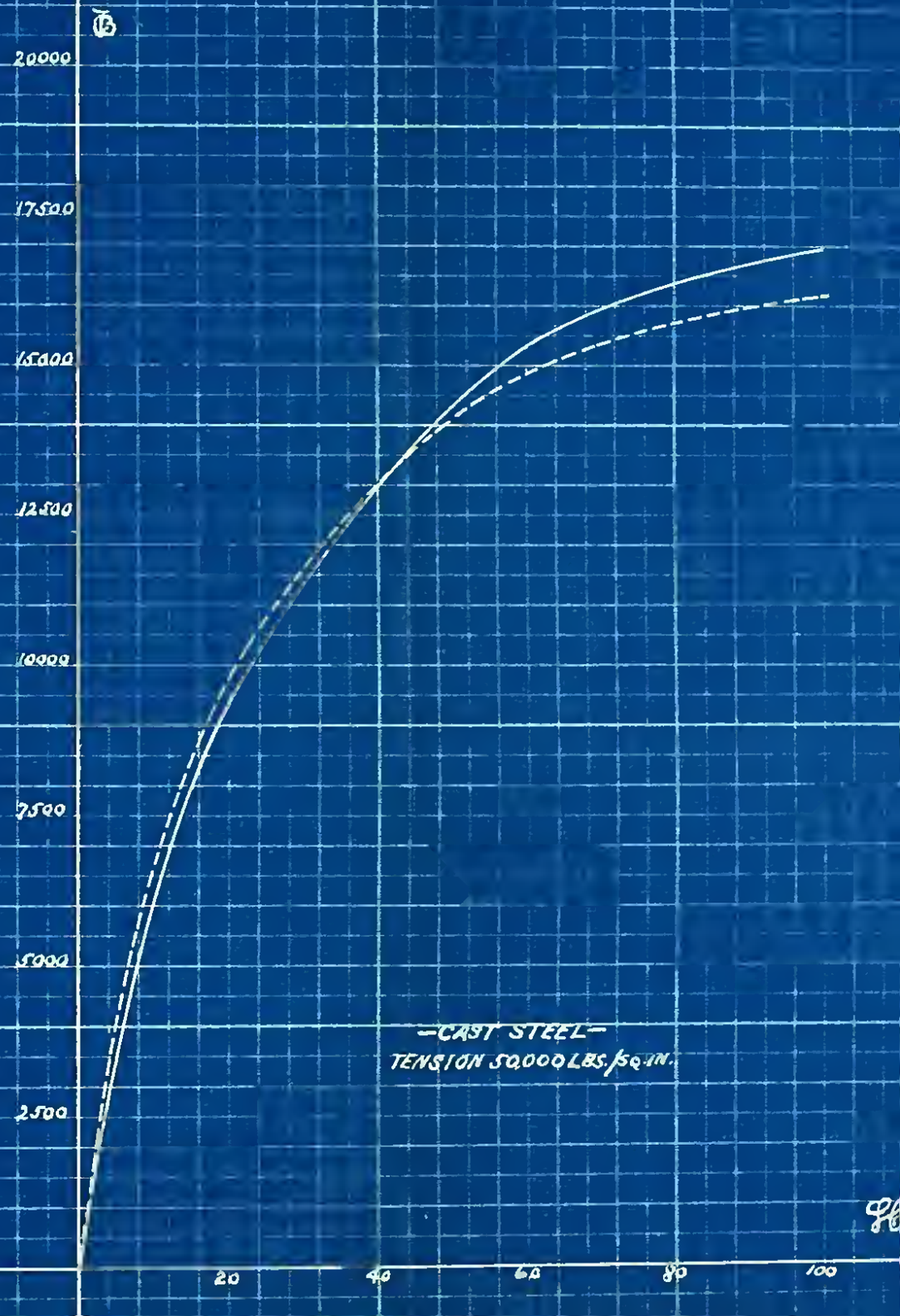
H	B	μ
20	9400	470.0
40	12950	323.8
60	15300	255.0
80	16350	204.4
100	16950	169.5

MAGNETIC BALANCE

H	B	μ
20	9800	490.0
40	13000	325.0
60	14850	247.5
80	15700	196.3
100	16150	161.5

PERMEAMETER

H	B	μ
20	9400	470.0
40	12950	323.8
60	15300	255.0
80	16350	204.4
100	16950	169.5



Data for B-H Curve of Cast Steel (6) After Being Subjected to a Tension of 90000 lbs./sq.in.

Obtained on Magnetic Balance.

B	H	B	H
14800	99.32	9000	-2.00
14000	64.00	8700	-4.66
12900	40.00	8500	-6.66
12100	26.00	8200	-8.00
11250	16.00	7400	-10.00
10600	10.00	6800	-12.00
10000	6.00	5600	-14.00
9600	2.00	3700	-16.00
9050	0.0	2200	-18.00
		60	-20.00
		0	-24.00
		-6800	-36.00
		-8200	-40.00
		-9150	-46.20
		-11100	-56.50
		-12550	-71.20
		-13750	-84.00
		-14700	-102.40

Data for B-H Curve of Cast Steel (F) After Being Subjected to a Tension Of 90000 lbs./ sq.in.

Obtained on Esterline's Permeameter

b	B	h	H
95000	14720	1000	99.00
92000	14250	800	79.20
91000	14100	600	59.40
70000	10850	400	39.60
68000	10550	320	31.60
66000	10220	240	23.76
50000	7750	120	11.88
36000	5580	40	3.96
32000	4960	0	0.0
-2000	-310	-160	-15.84
-14000	-2170	-200	-19.80
-24000	-3720	-240	-23.76
-30000	-4650	-280	-27.72
-50000	-7750	-360	-35.64
-60000	-9300	-440	-43.56
-74500	-11500	-560	-55.44
-87000	-13500	-720	-71.28
-98500	-15260	-880	-87.12
-103000	-16000	-1000	-99.00

MAGNETIC BALANCE

H	B	μ
20	5150	257.5
40	10150	253.8
60	12950	215.8
80	13850	173.2
100	14650	146.5

PERMEAMETER

H	B	μ
20	5700	285.0
40	10400	260.0
60	12800	213.3
80	14400	180.0
100	15300	153.0

STANDARD CROSS SECTION MILLIMETER
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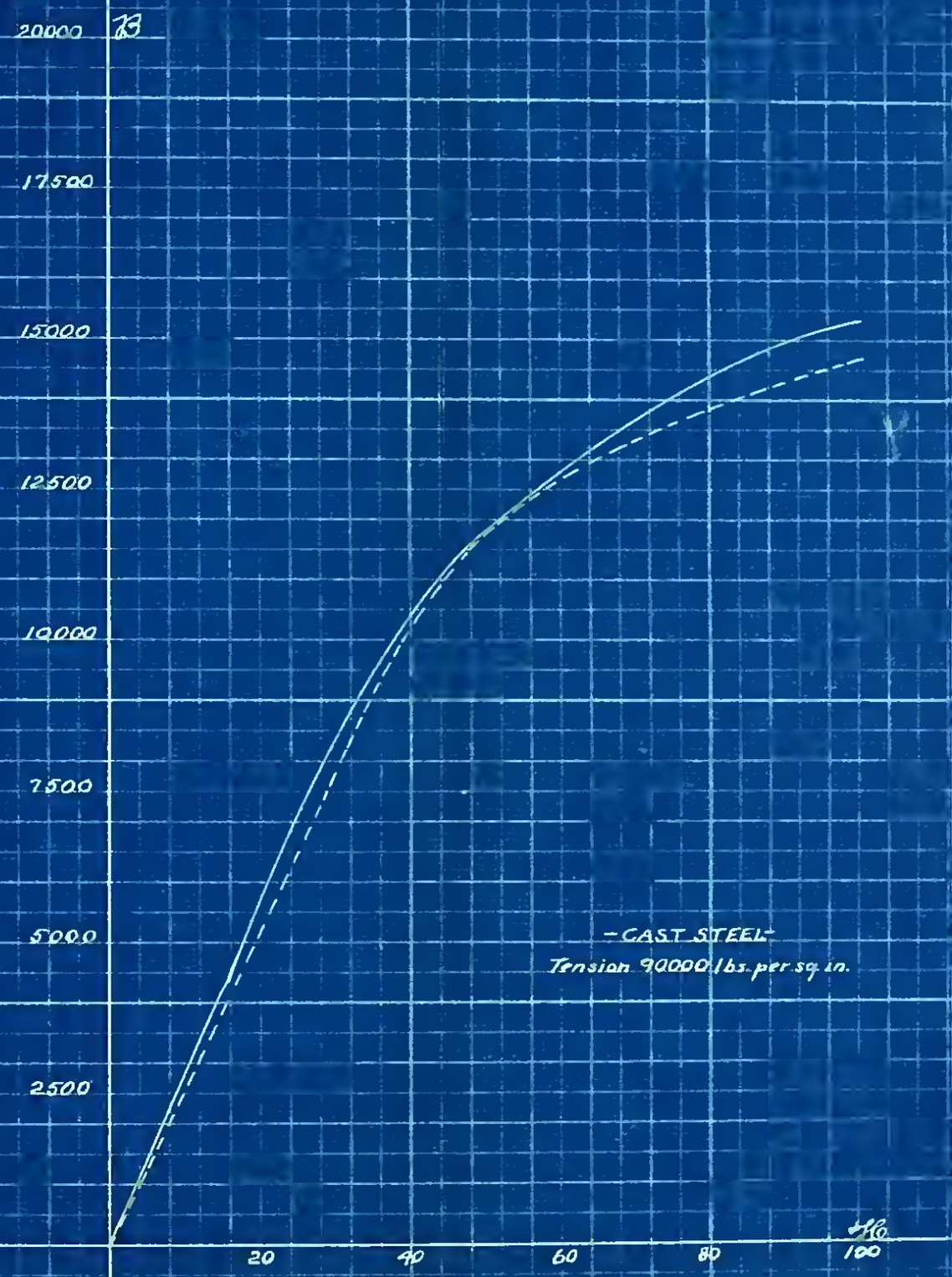
MAGNETIC BALANCE

H	B	μ
20	5150	257.5
40	10150	253.8
60	12950	215.8
80	13850	173.2
100	14650	146.5

PERMEAMETER

H	B	μ
20	5700	285.0
40	10400	260.0
60	12800	213.3
80	14400	180.0
100	15300	153.0



-Wrought Iron Tension Samples-

Permeability values obtained from curves.

Tension lbs./sq.in.	Magnetic Balance H	Magnetic Balance μ	Permeameter H	Permeameter μ
Initial Condition	20	813	20	640
	40	451	40	390
	60	312	60	278
	80	239	80	215
	100	193	100	176
5000	20	808	20	710
	40	444	40	429
	60	309	60	304
	80	238	80	238
	100	193	100	144
10000	20	825	20	685
	40	456	40	408
	60	318	60	290
	80	243	80	230
	100	197	100	186
15000	20	810	20	835
	40	443	40	474
	60	307	60	333
	80	237	80	259
	100	193	100	213
22000	20	823	20	708
	40	450	40	434
	60	312	60	308
	80	238	80	241
	100	193	100	199

-Soft Steel Tension Samples-

Permeability values obtained from curves.

Tension lbs./sq.in.	Magnetic Balance H	Magnetic Balance μ	Permeameter H	Permeameter μ
Initial Condition	20	840	20	708
	40	452	40	399
	60	311	60	281
	80	238	80	218
	100	194	100	179
5000	20	835	20	790
	40	446	40	438
	60	306	60	304
	80	237	80	261
	:100	192	100	202
15000	20	848	20	808
	40	451	40	440
	60	310	60	310
	80	237	80	243
	100	191	100	199
25000	20	840	20	860
	40	450	40	485
	60	308	60	338
	80	236	80	261
	100	192	100	213
50000	20	800	20	755
	40	435	40	445
	60	298	60	318
	80	230	80	248
	100	198	100	204

-Cast Steel Tension Samples-

Permeability values obtained from curves.

Tension lbs./sq.in.	Magnetic Balance H	Magnetic Balance μ	Permeameter H	Permeameter μ
Initial Condition	20	518	20	410
	40	335	40	306
	60	352	60	228
	80	200	80	183
	100	165	100	152
11900	20	440	20	465
	40	344	40	338
	60	256	60	247
	80	200	80	195
	100	164	100	161
30000	20	495	20	440
	40	360	40	315
	60	262	60	236
	80	207	80	189
	100	171	100	159
50000	20	490	20	470
	40	325	40	324
	60	248	60	255
	80	196	80	204
	100	162	100	170
90000	20	258	20	285
	40	254	40	260
	60	216	60	213
	80	173	80	180
	100	147	100	153

-Wrought Iron-

Annealing Samples

Permeability values obtained from curves.

Temp.	Time	Magnetic Balance H	Magnetic Balance μ	Permeameter H	Permeameter μ
Initial Condition		20	815	20	733
		40	466	40	422
		60	327	60	300
		80	250	80	233
		100	203	100	192
750°F.	2 hrs.	20	870	20	785
		40	473	40	430
		60	327	60	297
		80	250	80	230
		100	202	100	187
	4 hrs.	20	865	20	775
		40	456	40	422
		60	313	60	295
		80	240	80	229
		100	194	100	188
1000°F.	2hrs.	20	870	20	945
		40	455	40	495
		60	311	60	340
		80	237	80	259
		100	193	100	211
	4 hrs.	20	865	20	925
		40	450	40	497
		60	308	60	344
		80	236	80	265
		100	192	100	215
1800°F.	2 hrs.	20	865	20	963
		40	450	40	504
		60	307	60	350
		80	234	80	270
		100	189	100	222
	4 hrs.	20	920	20	880
		40	475	40	460
		60	325	60	320
		80	247	80	244
		100	201	100	199

-Soft Steel-

Annealing Samples

Permeability values obtained from curves

Temp.	Time	Magnetic Balance H	Magnetic Balance μ	Permeameter H	Permeameter μ
Initial Condition		20	855	20	690
		40	455	40	382
		60	310	60	271
		80	240	80	212
		100	192	100	176
750°F.	2 hrs.	20	815	20	750
		40	442	40	417
		60	306	60	292
		80	234	80	227
		100	190	100	187
	4 hrs.	20	840	20	800
		40	455	40	444
		60	315	60	308
		80	243	80	237
		100	196	100	196
1000°F.	2 hrs.	20	880	20	955
		40	462	40	510
		60	315	60	352
		80	240	80	270
		100	194	100	218
	4 hrs.	20	865	20	865
		40	460	40	460
		60	316	60	320
		80	242	80	246
		100	196	100	201
1800°F.	2 hrs.	20	830	20	850
		40	447	40	473
		60	308	60	340
		80	236	80	266
		100	192	100	218
	4 hrs.	20	820	20	830
		40	442	40	460
		60	307	60	320
		80	235	80	248
		100	190	100	202

-Cast Steel-

Annealing Samples

Permeability values obtained from curves.

Temp.	Time	Magnetic Balance H	Magnetic Balance μ	Permeameter H	Permeameter μ
Initial Condition		20	540	20	410
		40	340	40	300
		60	243	60	225
		80	183	80	178
		100	160	100	150
750°F.	2 hrs.	20	625	20	525
		40	372	40	325
		60	263	60	242
		80	205	80	195
		100	168	100	163
	4 hrs.	20	D	20	425
		40	N.a	40	312
		60	o t	60	235
		80	a	80	187
		100	.	100	155
1000°F.	2 hrs.	20	610	20	500
		40	370	40	375
		60	261	60	280
		80	204	80	222
		100	166	100	185
	4 hrs.	20	632	20	475
		40	356	40	316
		60	255	60	252
		80	201	80	201
		100	166	100	167
1800°F.	2 hrs.	20	600	20	560
		40	358	40	380
		60	257	60	280
		80	202	80	224
		100	167	100	186
	4 hrs.	20	630	20	505
		40	373	40	345
		60	267	60	259
		80	208	80	205
		100	171	100	180

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